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FISHERY RESEARCH

Job Performance Report

Project F-73-R-15

Subproject V, Study III

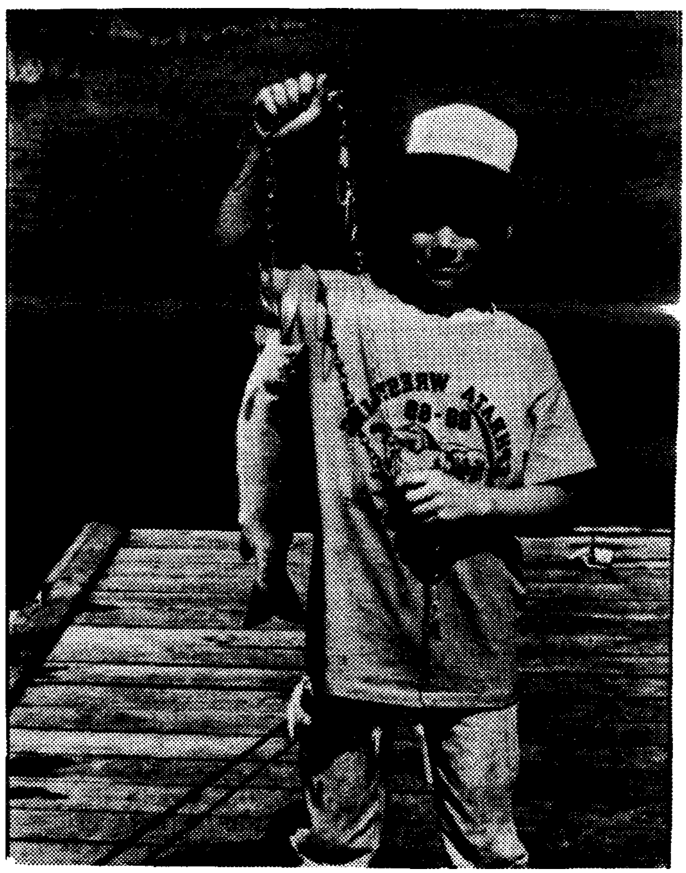
PUT-AND-GROW TROUT EVALUATIONS

Job 1. Synopsis of Information on Put-and-Grow Trout Management

Job 2. Put-and-Grow Versus Put-and-Take Stocking Experiments

Job 3. Hatchery Capabilities

Job 4. Rainbow Trout Strain Synopsis



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JOB PERFORMANCE REPORT

State of: Idaho

Name: Put-and-grow Trout Evaluations

Project No.: F-73-R-15

Title: Synopsis of Information on Put-and-Grow Trout Management

Subproject No.: V

Study No.: III

Job: 1

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ABSTRACT

This report provides a synopsis of available information on put-and-grow trout management. Because Idaho currently has no established guidelines for stocking put-and-grow trout, the information was used to propose preliminary guidelines for fish size and stocking rate.

Species and strain stocked, size and condition at stocking, lake productivity, forage availability, predation and competition can interact to affect stocking success. The degree to which these factors are important in Idaho fisheries is unclear. Put-and-grow trout are unlikely to yield cost-effective returns where predators and competitors are abundant. Periodic assessment of predator populations in put-and-grow trout waters would help determine appropriate sizes to plant.

Existing stocking guidelines from other states and Canada are probably not directly applicable to Idaho waters. They can, however, be used to characterize put-and-grow waters and provide general bounds for appropriate stocking rates. Stocking rate guidelines based on lake characteristics (productivity and fish community) were proposed for Idaho waters using these existing guidelines. For 75-100 mm trout stocking rate should not exceed 350 fish/hectare, and stocking rate for 150-175 mm trout should not exceed 200 fish/hectare, even in productive trout-only waters. Current stocking rates in some of our waters exceed 1,900 fish/hectare.

Ongoing evaluations of put-and-grow trout fisheries will be important to document cost-effectiveness of stocking and the factors influencing growth and returns. Stocking guidelines should be modified as new data become available.

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INTRODUCTION

Most of Idaho's lake and reservoir rainbow trout Oncorynchus mykiss fisheries are supported by hatchery plants of put-and-grow and put-and-take fish. Put-and-grow management is a cost-effective option when growth and survival of stocked fish is sufficient to allow them to recruit to the fishery. Some waters are stocked with smaller (75-100 mm) fish in the spring, some receive larger (100-150 mm) fish in the fall, and some receive both. Put-and-take rainbow trout (225-300 mm) are often stocked in addition to put-and-grow fish.

Put-and-grow management is attractive because the costs per fish stocked is much lower than for put-and-take fish. Hatcheries can provide many put-and-grow rainbow trout for the same cost as one put-and-take fish. Returns are typically much lower for put-and-grow fish, however, and the tradeoffs in the two management approaches are poorly defined in most of our waters. Current guidelines to judge success of put-and-grow management call for a 100% return by weight on planted fish (IDFG 1990). Because few comprehensive evaluations have been done, it is unclear how often we meet this guideline. Consequently, we have very little information on which to judge the success of put-and-grow trout management in Idaho.

Regional Fishery Managers currently develop stocking requests (number, species, size, and timing) for individual fisheries. Requests are usually based on little or no evaluation data, and may often be a "best guess" or simply maintenance of past stocking strategies. We have no established guidelines with which we can select appropriate management options. A simple example would be the number of 75-100 mm trout/hectare to plant in low-productivity lakes and reservoirs, or some minimum level of lake productivity necessary for successful put-and-grow management.

Because we have no stocking guidelines, stocking strategies and stocking rates vary tremendously across the state. Past stocking rates for put-and-grow fish have ranged from a few fish to over 1900 fish/hectare.

A summary of existing data on put-and-grow trout fisheries in Idaho and elsewhere could provide general guidelines for put-and-grow management. Describing lake characteristics associated with successful and unsuccessful put-and-grow fisheries would help us describe the likelihood of success in our waters. Ongoing put-and-grow stocking experiments (Job 2, this report) will allow us to further refine stocking strategies, define tradeoffs between put-and-grow and put-and-take management, and optimize use of hatchery products.

OBJECTIVES

1. To provide a synopsis of put-and-grow literature.

2. To describe current management of put-and-grow trout in other states.

3. To describe lake characteristics important to put-and-grow trout performance.

4. To summarize stocking relationships for put-and-grow trout in Idaho.

5. To develop interim recommendations for put-and-grow trout management and stocking strategies in Idaho.

METHODS

General Synopsis

We conducted a comprehensive review of the literature on put-and-grow trout management. Of specific interest was describing lake characteristics associated with success or failure of put-and-grow fish, and the relationships between stocking densities, size, predators and competitors, and growth and survival. We contacted biologists in other states to describe their stocking guidelines and strategies, including stocking densities, sizes and timing, and compared them to current practices in Idaho.

Stocking Relationships

We summarized data from existing IDFG reports to describe relationships among put-and-grow rainbow trout stocking rates, catch rates, returns and effort.

RESULTS

General Synopsis

Performance of put-and-grow trout (measured as growth, survival or returns) is highly variable among lakes and within lakes over time. Many factors can interact to determine the success or failure of a given plant. These include: 1) species/strain stocked; 2) size and condition at stocking; 3) lake productivity and forage availability; 4) water quality; 5) predation; and, 6) competition (both inter- and intraspecific).

Species and Strain

A complete synopsis of strain influences on rainbow trout survival and performance is provided in Job 4, this report. For put-and-grow trout, wild strains tend to have higher survival and greater longevity than domesticated strains, although catchability may be higher for domestic strains. Differences in performance among domestic strains appear inconsistent.

Size and Condition at Stocking

Size at stocking has a direct influence on survival. Larger stocked fish typically return at higher rates than smaller fish in the same water (Keating 1961; Boles et al. 1964; Hansen and Stauffer 1971; Turner 1977; Moore et al 1983; Reininger et al. 1983; Havens 1984; Elie et al. 1987; Maiolie 1987; Minnesota Department of Natural Resources 1991). Sub-catchable -size trout may provide other benefits, however, by contributing to the creel over a longer period and reaching larger sizes than catchable fish which are quickly harvested (Turner 1977).

Size at stocking is more important in lakes with complex fish communities. Larger fish survive better in the presence of competitors or predators, and stocking catchable size fish may be necessary where competitors or predators are abundant (Avery 1975; Potter and Barton 1986; Pennsylvania Fish Commission 1987; Ecologistics Limited 1990). In trout-only lakes, size at stocking is less important unless existing trout in the lake are piscivorous (e.g. Smith 1968).

There is little more than anecdotal reports suggesting that condition at stocking has a major influence on survival and returns. We found no guidelines in the papers reviewed for recommended levels of physical conditioning, fat reserves, etc. to optimize post-stocking performance. Goede (1987) proposed procedures to assess health and condition of fish in the wild or in the hatchery. He recommends target pyloric fat indices (PFI) of 1.0 for put-and-take fish for which long-term survival is not expected. Put-and-grow fish that must survive on energy stores until they adapt to natural foods should have PFIs of 2-3 at stocking (Ron Goede, Utah Division of Wildlife Resources, personal communication).

Productivity and Forage Availability

Several authors reported positive relationships between lake or reservoir productivity and trout growth, but the indices of productivity they used varied. Gipson and Hubert (1991) reported a strong positive relationship between condition of salmonids (and presumably growth) and total dissolved solids (TDS) in 13 Wyoming reservoirs. Donald and Anderson (1982) found growth of rainbow trout in 23 mountain lakes was positively correlated with TDS and negatively correlated with elevation and stocking density. They suggest that mountain lakes with <500 ppm TDS will not produce large fish and should be stocked with <100 fish/hectare. Artificial fertilization of a small lake increased growth of planted and native brook trout Salvelinus fontinalis (Smith 1968).

The total forage community in a lake or reservoir may have important implications for potential growth of trout. Trout can grow well and reach large sizes on a variety of invertebrate forage (Cooper 1959; Crossman and Larkin 1959), but zooplankton forage alone may not provide growth past 350 mm (Hensler 1987). Trout switch from zooplankton to other larger forage items as they grow (Jarcik and Dillon 1992) presumably because of decreased feeding efficiency on zooplankton (Hensler 1987). Growth of larger trout may decline if other macroinvertebrate prey are unavailable. Fish forage can increase the growth of larger trout, but may compete with smaller trout for zooplankton or other invertebrate forage (Crossman and Larkin 1959). In basic yield fisheries, it is more important to exclude forage fish from trout waters because shortening the food chain one trophic level will increase trout production several-fold (Cooper 1959).

Water Quality

Relatively little work has specifically addressed water quality effects on put-and-grow trout. Dissolved oxygen and temperature are the most important abiotic factors determining the suitability of waters for trout (Ontario Ministry of Natural Resources 1982). Although tolerances can differ among species and strains, trout survival is generally reduced at temperatures above 21 C^0 and oxygen levels below 3 ppm (Threinen 1959). Low levels of dissolved oxygen (<3 ppm) were associated with decreased growth and survival of stocked trout in Lake Taneycomo, Missouri (Lake Taneycomo Management Committee 1988). Temperature and oxygen profiles are useful to describe usable volume or area for trout in a lake (Fish 1963; Stocekand MacCrimmon 1965; Van Velson 1986; Heimer and Howser 1990).

Predation

Predation on stocked trout can strongly influence stocking success. In general, stocking put-and-grow trout is most successful in the absence of predators and competitors (Stuber et al. 1985). Important predators may include birds, mammals, or resident fish (Smith 1968; Keith and Barkley 1970; Avery 1975; Dufek et al. 1980; Stuber et al. 1985; Hepworth and Duffield 1991). Predator control was more important than lake fertilization in increasing returns of fingerling brook trout in a small lake (Smith 1968). Avery (1975) found 84-94 mm brown trout <u>Salmo</u> <u>trutta</u> and rainbow trout in smallmouth bass <u>Micropterus dolomieui</u> stomachs shortly after the trout were stocked. Keith and Barkley (1970) reported that largemouth bass M. <u>salmoides</u> >400 mm in length averaged five trout consumed per bass in an Arkansas lake. Dufek et al. (1980) attributed the failure of the fingerling rainbow trout program in Flaming Gorge Reservoir, Utah in part to predation by resident lake trout <u>Salvelinus</u> <u>namaycush</u> and brown trout. Stuber et al. (1985) considered predation by brown trout to contribute to poor returns of fingerling rainbow trout in Dillon Reservoir, Colorado. Hepworth and Duffield (1991) suggested poor returns of early spring-stocked rainbow trout in a Utah reservoir were due to predation by migrating birds. Northern squawfish <u>Ptychocheilus</u> <u>oregonensis</u> were considered to compete with and prey on stocked trout in Cascade Reservoir (Irrizary 1970). Several unsuccessful attempts were made to decrease northern squawfish populations using both rotenone and the selective piscicide squaxin (Irrizary 1970; Lindland 1971, 1972, 1973; Welsh 1975).

Better returns from large fingerlings or catchable-size fish in some waters is related to lower susceptibility to predation. Wyoming stocking guidelines suggest stocking only rainbow trout >230 *mm in* waters where average walleye

Stizostedion vitreum length exceeds 457 mm (Wayne Fornstrom, Wyoming Game and Fish Department, personal communication). Keith and Barkley (1970) concluded that rainbow trout must be at least 250 mm to avoid predation by largemouth bass.

Competition

Interspecific competition is considered an important limitation to growth and survival of stocked trout. In most papers reviewed, however, competitive interactions were implied rather than quantified. Atkinson (1932) reported better trout growth in ponds without minnows and with abundant *Gammarus* than in ponds with minnows present and low *Gammarus* densities. Growth of stocked rainbow trout fry declined in Paul Lake, British Columbia after redside shiners *Richardsonius balteatus* became established (Crossman and Larkin 1959). As the redside shiners increased in abundance, amphipods became rare in trout diets. Stuber et al. (1985) suggested competition from kokanee *Oncorhynchus nerka* for limited zooplankton contributed to poor returns of fingerling rainbow trout in Dillon Reservoir, Colorado. Avery (1975) reported excellent survival, growth and returns from 84-94 mm trout planted in Nebish Lake, Wisconsin after it was renovated. Six years later, the lake had a stunted yellow perch *Perca flavescens* population and smallmouth bass; a similar trout plant had virtually zero survival. Establishment of yellow perch led to a shift in diet and reduced growth and survival of stocked trout in a small Ontario lake (Fraser 1978). Havens (1984) reported better growth and survival of stocked rainbow trout fry in rehabilitated lakes than in lakes with sticklebacks *Gasterosteus* app. Havens and Sonnichsen (1992) similarly implied competition with sticklebacks reduced trout growth in Alaskan lakes. In Flaming Gorge Reservoir, Dufek et al. (1980) reported that increases in Utah chub *Gila atraria* and white suckers *Catostomus commersoni* coincided with the decline in trout stocking success. The presence of white suckers and longnose suckers *C. catostomus* reduced the growth of stocked rainbow trout in an Alberta reservoir, presumably through competition for zooplankton (Barton and Bidgood 1980).

In general, returns of stocked trout decrease as community complexity increases (Fraser 1972; Ontario Ministry of Natural Resources 1982). Cooper (1959) concluded the best returns of planted trout are likely to occur when little or no competition exists. Fishery biologists have accepted this concept, and lake renovations to reduce or eliminate interpecific competition are common (Borgeson 1987).

In contrast to most studies implying competition is important, Marin and Erman (1982) found no evidence of strong competition among tui chub *Gila bicolor*, Tahoe sucker *Catostomus tahoensis*, and rainbow and brown trout in Stampede Reservoir, California. They suggested that the decline in fingerling rainbow trout stocking success was due to decreasing reservoir productivity and predation by large resident brown trout.

Intraspecific competition and predation can also influence growth and survival of put-and-grow trout. Several authors noted an inverse relationship between trout stocking densities and growth (Mottley 1941; Crossman and Larkin 1959; Donald and Anderson 1982; Havens and Sonnichsen 1992). An increase in stocking density should produce more but smaller trout. At some point, however, it is likely that crowding will increase mortality and that additional stocking will increase neither production nor numbers of trout (Donald and Anderson 1982). McAfee (1991) suggested that fingerling trout growth and survival was related more to existing trout densities in the reservoir than to stocking density or size. She noted that overstocking or high survival of a plant could suppress subsequent plants.

Relationships between stocking density, growth and lake productivity have been used to predict stocking rates required to attain a given growth rate or size at harvest (Donald and Anderson 1982; Borgeson 1987).

Stocking Guidelines

Other than the generalities derived from the literature on put-and-grow trout, there are few published guidelines on stocking strategies. Most natural resource agencies in other western states have proposed minimum acceptable return rates, by number or weight, for stocked fish. However, none have specific criteria on which to select put-and-grow versus put-and-take management, or to determine appropriate stocking rates. Most put-and-grow stocking programs have been developed through a process of trial and error. Biologists in every state surveyed acknowledged the need for more specific guidelines.

Montana is increasing emphasis on wild strains with greater longevity (Eagle Lake and DeSmet), but stocking rates, size and timing are variable (Dick Vincent, Montana Department of Fish, Wildlife and Parks, personal communication). The wild strains persist up to 6-7 years, thus the fisheries are less reliant on the success of individual plants. They report consistently poor success of late summer and fall fingerling plants. Wyoming, Utah, Colorado, and Oregon also have no formal stocking guidelines. Utah has some unwritten guidelines developed by trial end error over the years. For example, they found the best returns of 150 mm fingerlings are from trout-only waters, and larger fish are necessary when competitors or predators are present (Dale Hepworth, Utah Department of Natural Resources, personal communication). Chris Leucke (Utah State University, personal communication) is working on a model to predict growth and survival of stocked fingerling trout based on zooplankton densities and predator abundance (fish and birds).

In other states and Canada, some trout (fry, fingerling, and catchable) stocking guidelines have been developed (Smith et al. 1969; Johnson 1978; Ontario Ministry of Natural Resources 1982; Hooper 1985; Krueger and Dehring 1986; Borgeson 1987; Pennsylvania Fish Commission 1987). Some provide specific guidelines for stocking rate and size, while others simply list lake or fish community characteristics necessary for successful put-and-grow trout programs. Most proposed stocking formulas require a judgement or measurement of lake productivity and abundance of predators and competitors, but other factors such as water chemistry, frequency of winter kill, angling pressure, and available habitat (temperature and oxygen profiles) may also be included.

Examples of put-and-grow trout stocking rate guidelines from other states are provided in Appendix A. Trout stocking in Minnesota is limited to renovated lakes. Recommended stocking rates for 50-100 mm rainbow trout vary from 123/hectare in lightly fished lakes with frequent winter kill to 618/hectare in more productive and heavily fished waters (Johnson 1978). Michigan developed a simplified trout stocking table based on expected yield (a composite of lake productivity and abundance of competitors), percent return, and average size of trout in the creel (Borgeson 1987). They suggest 120 to 370 75-100 mm trout/hectare in trout-only lakes, and recommend larger (125-175 mm) trout in multispecies waters. In New Brunswick, stocking rates guidelines are based on lake productivity (morphoedaphic index), proportion of littoral (productive) zone relative to total area, abundance of competitors and predators, and relative angling pressure (Hooper 1985). Guidelines for fingerling trout stocking in Pennsylvania are based on predicted yield, estimated standing crop of the fish community, and projected survival of different sizes of trout (Pennsylvania Fish Commission 1987).

For mountain lakes in Colorado, Nelson (1987) developed stocking rate recommendations based on elevation and angling effort. Donald and Anderson (1982) developed a model to derive rainbow trout stocking rates for mountain lakes based on TDS, mean depth, and desired fish weight at age 2.

Stocking rates for several Idaho waters, and recommended stocking rates based on existing guidelines (Johnson 1978; Ontario Ministry of Natural Resources 1982; Borgeson 1987; Pennsylvania Fish Commission 1987) are presented in Table 1. Recommended stocking rates varied up to an order of magnitude among the different guidelines. Stocking rates for Minnesota (Borgeson 1987) are higher than the others, probably in part because Minnesota stocks trout only in renovated waters. Of the twelve waters and stocking rates compared, nine of the Idaho stocking rates are similar to recommended rates from Ontario, Michigan, and Pennsylvania. Stocking rates in Winchester Reservoir, Spring Valley Reservoir, and Manns Lake were 2-3 times the highest recommended rate.

Stocking Relationships

I reviewed 64 past Idaho reports where some form of evaluation took place on a put-and-grow trout water. Thirty-eight of these provided various combinations of stocking rate, catch rate and return data (Appendix B). Evaluations ranged from spot creel checks to year-round full censuses. Only eight evaluations provided catch rate data specifically for put-and-grow fish, and thirteen documented put-and-grow returns. With the few data points available, the relationships between stocking rate and catch rate or between effort and returns are poorly defined (appendices C and D). In the future, data from the new evaluations may be used to supplement these data and clarify the relationships.

Table 1. 1993 put-and-grow trout requests (fish/hectare) for select Idaho waters, and comparisons to recommended stocking rates based on five different stocking formulas or guidelines.

	1993 Requests			Recommended stocking rates (fish/hectare) based on guidelines from				
					Ontario[b]			
Water	Total Number	Number/hectare	size (in.)	MN[a]	A	B	MI[c]	PA[d]
Hauser	18,000	81	6	124-371	40	51	12-62	84
Winchester	65,000	1,912	3-7	490-[illegible]	70	148	62	128
Spg Valley	40,000	1,905	3-7	490-[illegible]	47	113	62	86
Manns L.	60,000	1,224	3	490-620	361	749	62	395
Moose Cr.	15,000	750	5-7	490-[illegible]	63	115	62	128
C.J. Strike	500,000	165	6-8	62-185	47	74	62	153
Ind. Cr Res.	11,000	122	4-6	124-371	107	308	62	128
Brownlee	450,000	87	4-8	125-185	61	-	62	12-[illegible]
Crane Falls	8,000	211	6-8	124-247	53	112	62	174
And. Ranch	200,000	104	3	124-371	229	-	12-62	78
Twin Lakes	37,640	208	5-7	247-[illegible]	49	99	62	100
Ririe	235,000	372	3	247-494	346	339	62	119

[a] Johnson (1978); recommended stocking rates are for trout-only waters

[b] Ontario Ministry of Natural Resources (1982); cites two approaches, A = the modified OMNR method (Anon. 1970) and B = the modified New York Method (Engstrom-Heg 1979).

[c] Borgeson (1987); recommended stocking rates are for 5-7" fish

[d] Pennsylvania Fish Commission (1987)

DISCUSSION

General Synopsis

Many factors interact to determine the success of put-and-grow trout stocking. Lakes and reservoirs are dynamic systems. The relative importance of various factors on put-and-grow performance will differ from water to water, and likely from year to year in the same water. Regardless of this variability, some common trends are evident from the literature review and discussions with other biologists.

The species or strain of trout stocked can have a marked influence on performance. The differences among domesticated strains are probably small, but the differences between domestic and wild strains appears significant (Job 4, this report). Wild strains of rainbow trout have shown consistently better survival and greater longevity, although they may be less catchable than domestic strains. Wild strains can provide benefits in put-and-grow fisheries in several ways. Higher survival means lower stocking rates to provide the same level of fishery. Greater longevity increases the potential to reach trophy size if adequate forage is available. Also, because up to 4-5 year classes may persist, the fishery becomes less dependent on the success of an individual year's stocking.

Because survival and returns of put-and-grow fish are positively correlated with growth (Atkinson 1932), it would be useful to quantify the relationship between lake productivity and growth. However, the influence of primary productivity on trout growth varies with community complexity. In simple trout-only systems, productivity can be a reasonable predictor of fish yield, but growth is still probably density dependent above a certain threshold. In lakes with complex communities (including most of Idaho's waters), I suggest there may be little or no relationship between primary productivity and trout growth. The data currently available is insufficient to fully describe the relationships between fish densities, growth, and indices of lake productivity.

Many studies have shown a positive relationship between size at stocking and survival or returns. Optimum size will vary depending on lake productivity, predator population characteristics, and possibly competition levels. Small (75-100 mm) trout will probably yield consistently poor returns where predators are abundant; larger subcatchable or catchable size fish may be required for cost-effective stocking programs.

Size-at-stocking and post-stocking growth also influence when stocked fish recruit to the fishery. Post-stocking growth varies among waters and within waters over time. Stocked fish that grow poorly and require two growing seasons to reach acceptable size to the angler are unlikely to return in significant numbers.

Specific guidelines for fish condition to maximize survival and returns are unavailable from the existing literature. Common sense would dictate that fish stocked in good condition will yield better returns than fish in poor condition.

Our hatcheries currently have no guidelines for fish condition (e.g. minimum K-values, relative weight, pyloric fat index). It is fairly routine to reduce feeding or take fish off feed for extended periods in response to low hatchery flows or other water quality problems. Under these circumstances stocked fish can have virtually no energy reserves on which to survive until they adapt to feeding in the lake. Though it remains unclear what the exact benefits are, some guidelines for condition at stocking would be useful to minimize variability in hatchery products. Adopting the PFI standards used in Utah (Ron Goede, personal communication), at least on an interim basis, is probably reasonable until we have data to refute or support them.

We have substantial predator fish populations in many of the waters where we stock put-and-grow trout, and virtually no data to assess past stocking success. Developing size-at-stocking criteria for these waters would be a useful initial step to improve returns. The most straight forward way to describe appropriate sizes to stock may be to assess predator population abundance and size structure, similar to Wyoming's approach in walleye waters. Where predators are abundant, stocked fish should be of a size unavailable to a majority of the predator population.

The -importance of competition in our put-and-grow waters is unclear. Competition is often implied when trout growth or returns are poor, but measurements of dietary and spacial overlap between trout and potential competitors have not been made in most waters. The preliminary data we have on zooplankton size structure in our waters suggests that zooplankton cropping is not a problem, even where potentially competing species are abundant (Dillinger 1993). Competition could also, however, limit availability of other macroinvertebrate prey. This could be particularly important for larger trout which rely on a more diverse forage base to maintain growth. Monitoring zooplankton abundance and size structure and relationships to trout growth will be an important priority for the new evaluations.

Existing stocking guidelines for put-and-grow trout are generally based on combinations of lake productivity, abundance of competitors and predators, and fishing effort. They were developed for other states and provinces based on either empirical data or the cumulative experience of biologists. The wide range in recommended stocking rates probably reflects regional differences in lake and reservoir characteristics and also in the methods by which the recommendations were developed. Although these guidelines may not be directly applicable to Idaho waters, they may provide some bounds for reasonable stocking rates, sizes, etc. For example, in some Idaho lakes we have stocked up to 2-3,000 fingerlings/hectare (Table 1, Appendix B). Existing guidelines suggest that such high stocking rates are unlikely to yield cost-effective returns, and probably represent an inefficient use of hatchery products.

Based on a composite of existing stocking guidelines (Appendix A), I developed interim guidelines for stocking put-and-grow fish in Idaho waters (Table 2). These guidelines should be modified as ongoing experiments provide the necessary information on relationships among size at stocking, stocking rate, growth, returns, lake productivity, and species composition.

Table 2. Interim stocking guidelines for put-and-grow trout in Idaho lakes and reservoirs.

Lake Type		Stocking Rate (fish/hectare) Spring 75-100 mm	Fall 150-175 mm
Trout-only,	low productivity (MEI 1-3)	125-175	50-100
	med productivity (MEI 3-5)	200-250	75-150
	high productivity (MEI 5-10)	250-350	100-200
Multispecies			
	low productivity	75-100	50-75
	high productivity	150-175	75-125

CONCLUSIONS

Although we currently have little data with which to judge the success of our put-and-grow trout program, information from the literature can be used to provide some preliminary stocking guidelines. Stocking strategies should be site-specific, and reflect the productivity and species composition of the receiving water.

Predation and competition are the factors most often implicated when returns of stocked trout are low. Returns of small (<150 mm) put-and-grow trout stocked in waters with abundant predators or competitors are likely to be poor, and stocking fewer, larger fish may be more cost effective in providing fish in the creel. Periodic assessment of predator population size structure would help determine appropriate sizes to stock. High priority should be given to evaluations of put-and-grow trout where predators and competitors are present.

Existing stocking guidelines may not be applicable to Idaho waters. They are, however, useful to describe general stocking strategies that are likely to be successful or cost-effective. Existing guidelines suggest that put-and-grow stocking rates should not exceed about 620 75-100 mm fish/hectare (Michigan guidelines), even in highly productive single species trout fisheries. Other guidelines suggested maximum stocking rates of 250-350 fish/hectare. Our stocking rates on some waters exceed these figures, and data to assess cost effectiveness is lacking. Quantifying return rates and cost per harvested fish is important to support high stocking rates, or to adjust them.

The importance of time of stocking (spring or fall) was rarely addressed in the literature reviewed. Fall plants are typically larger fish, and size effects on survival cloud the influence of season. Fall fingerling production has increased in Idaho in the last few years. Because the expected benefits are unclear, it is important to evaluate both fall and spring plants to describe their relative benefits.

RECOMMENDATIONS

1. Interim stocking guidelines for spring and fall put-and-grow trout are proposed in Table 2. Stocking rates above these figures should be based on evaluations indicating acceptable returns. The guidelines should be modified as data from ongoing evaluations become available.

2. Choose size at stocking (put-and-take versus put-and-grow) based on existing species composition and predator population size structure. Stocked fish should be of a size unavailable to a majority of the predator population. Where potential competitors are abundant, emphasize put-and-take management unless evaluations demonstrate acceptable returns of put-and-grow fish.

3. In basic yield fisheries, use wild stocks for put-and-grow plants and domestic stocks for put-and-take.

4. Use the PFI to assess condition of hatchery fish at stocking. Sacrifice 30 fish from each major plant for internal examination. A preliminary target for condition at stocking should be a mean PFI of 1 for put-and-take fish and 2 to 3 for put-and-grow fish. This target should be adjusted as evaluation data becomes available to assess condition-at-stocking effects on returns.

5. Quantitatively describe lake and reservoir characteristics (productivity, species composition, predator abundance) associated with the growth and return rates of put-and-grow trout for future refinement of stocking guidelines.

6. Increase evaluation of put-and-grow trout stocking programs, with priority given to waters with established predator and competitor populations, or where both spring and fall put-and-grow fish are planted. Evaluations should include estimates of growth and percent return (by number and weight) and costs (per fish or kilogram). Where cost of harvested put-and-grow fish exceed that of put-and-take fish, emphasis should be placed on put-and-take management.

LITERATURE CITED

Atkinson, N.J. 1932. A study of comparative results from stocking barren lakes with rainbow trout. Transactions of the American Fisheries Society 62:197-201.

Avery, E.L. 1975. An evaluation of stocking fingerling trout in a "two-story" trout lake. Research Report No. 83, Wisconsin Department of Natural Resources, Madison, WI.

Barton B.A. and B.F. Bidgood. 1980. Competitive feeding habits of rainbow trout, white sucker and longnose sucker in Paine Lake, Alberta. Fisheries Research Report 16, Alberta Energy and Natural Resources, Calgary, Alberta.

Boles, H.D., F.A. Meyer, and D.P. Borgeson. 1964. Packer Lake experimental trout management. Inland Fisheries Administrative Report No. 64-12, California Department of Fish and Game, Sacramento, CA.

Borgeson, D.P. 1987. Michigan fish stocking guidelines. Fisheries Management Report No. 11, Michigan Department of Natural Resources, Lansing, MI.

Cooper, E.L. 1959. Trout stocking as an aid to fish management. Pennsylvania Agricultural Experiment Station Bulletin No. 663.

Crossman, E.J. and P.A. Larkin. 1959. Yearling liberations and change of food as affecting rainbow trout yield in Paul Lake, British Columbia. Transactions of the American Fisheries Society 88:36-44.

Donald, D.B. and R.S. Anderson. 1982. Importance of environment and stocking density for growth of rainbow trout in mountain lakes. Transactions of the American Fisheries Society 111:675-680.

Dufek, D., W. Wengert, and M. Snigg. 1980. Flaming Gorge Reservoir fisheries investigations; 1975-79 program summary. Publication No. 80-19, Utah Division of Wildlife Resources, Salt Lake City, UT.

Ecologistics Limited. 1990. An Assessment of the use of hatchery stock for fisheries management. Prepared for: Fisheries Branch, Fish Culture Section, Ontario Ministry of Natural Resources.

Elle, S., C. Corsi, and D. Aslett. 1987. Regional fisheries management investigations. Job Performance Report, Project F-71-R-11, Idaho Department of Fish and Game, Boise, ID.

Fish, G.R. 1963. Limnological conditions and growth of trout in three lakes near Rotorua. New Zealand Ecological Society Proceedings 10:1-7.

Fraser, J.M. 1972. Recovery of planted brook trout, splake, and rainbow trout from selected Ontario lakes. Journal of the Fisheries Research Board of Canada 29:129-142.

Fraser, J.M. 1978. The effect of competition with yellow perch on the survival and growth of planted brook trout, splake, and rainbow trout in a small Ontario lake. Transactions of the American Fisheries Society 107:505-517.

Gipson, R.D. and W.A. Hubert. 1991. Factors influencing the body condition of rainbow trout in small Wyoming reservoirs. Journal of Freshwater Ecology 6:327-334.

Goede, R.W. 1987. Fish health/condition assessment procedures. Colorado Division of Wildlife, Denver, CO.

Hansen, M.J. and T.M. Stauffer. 1971. Comparative recovery to the creel, movement and growth of rainbow trout stocked in the Great Lakes. Transactions of the American Fisheries Society 2:336-349.

Havens, A.C. 1984. Population studies of game fish and evaluation of managed lakes in the upper Cook Inlet drainage. Alaska Department of Fish and Game, Volume 25, Study G-III.

Havens, A.C. and S. Sonnichsen. 1992. Evaluation of enhancement efforts for rainbow trout in southcentral Alaska. Fisheries Data Series No. 92-37, Alaska Department of Fish and Game, Anchorage, Alaska.

Heimer, J.T. and S.T. Howser. 1990. American Falls Reservoir studies. Job Performance Report, Project F-71-R-12, Idaho Department of Fish and Game, Boise, ID.

Hensler, M.E. 1987. A field evaluation of four strains of Salmo introduced into seven Montana waters. Master's Thesis, Montana State University, Bozeman, MT.

Hepworth, D.K. and D.J. Duffield. 1991. Survival and return to the creel of fingerling rainbow trout stocked at different times of the year in Minersville Reservoir, Utah. Publication No. 91-8, Utah Department of Natural Resources, Salt Lake City, UT.

Hooper, W.C. 1985. Hatchery production and stocking guidelines for sport fisheries management in New Brunswick. Fishery Management Report No. 12, Fish and Wildlife Branch, Department of Forests, Mines and Energy, Fredericton, New Brunswick, Canada.

Idaho Department of Fish and Game. 1990. Fisheries management plan 1991-1995. Boise, ID.

Irrizary, R. 1970. Lake and Reservoir investigations. Annual Completion Report, Projects F-53-R-4 and F-53-R-5, Idaho Department of Fish and Game, Boise, ID.

Jarcik, K.A. and J.C. Dillon. 1992. Rainbow trout food habits investigations. Job Performance Report, Project F-73-R-14, Job 3, Idaho Department of Fish and Game, Boise, ID.

Johannes, R.E. 1961. Competition for food between redside shiners (Richardsonius balteatus) and rainbow trout (Salmo gairdneri) in two British Columbia lakes. Journal of the Fisheries Research Board of Canada 18:203-220.

Johnson, M.W. 1978. The management of lakes for stream trout and salmon. Special Publication No. 125, Minnesota Department of Natural Resources.

Keating, J.F. 1961. The survival of planted trout to the creel as related to their size and time of planting. Idaho Department of Fish and Game, Boise, ID.

Keith, W.E. and S.W. Barkley. 1970. Predation on stocked rainbow trout by chain pickerel and largemouth bass in Lake Quachita, Arkansas. Proceedings of the Southeastern Association of Game and Fish Commissioners, September 28-30, 1970.

Krueger, C.C. and T.R. Dehring. 1986. A procedure to allocate the annual stocking of salmonids in the Wisconsin waters of Lake Michigan. Fish Management Report 127, Wisconsin Department of Natural Resources, Madison, Wisconsin.

Lake Taneycomo Management Committee. 1988. Lake Taneycomo white paper. Missouri Department of Conservation, Jefferson City, MO.

Lindland, R.L. 1971. Squawfish control in Cascade Reservoir. Annual Completion Report, Project F-53-R-6, Idaho Department of Fish and Game, Boise, ID.

Lindland, R.L. 1972. Squawfish control in Cascade Reservoir (research). Job Progress Report, Project F-53-R-7, Idaho Department of Fish and Game, Boise, ID.

Lindland, R.L. 1973. Squawfish control in Cascade Reservoir (research). Job Progress Report, Project F-53-R-8, Idaho Department of Fish and Game, Boise, ID.

Maiolie, M.A. 1987. Ashton Reservoir fishery enhancement evaluation. Job Completion Report, Idaho Department of Fish and Game, Boise, ID.

Marrin, D.L. and D.C. Erman. 1982. Evidence against competition between trout and nongame fishes in Stampede Reservoir, California. North American Journal of Fisheries Management 2:262-269.

McAfee, M.E. 1991. Stocking plan evaluations. Final Report, Job 1, Project F-59, Colorado Division of Wildlife, Denver, CO.

Minnesota Department of Natural Resources. 1991. Effect of size at stocking on harvest of rainbow trout in Bad Medicine Lake: a benefit-cost analysis. Progress Report-, Project 1F-26-R-22, Study 641,-Minnesota Department of Natural Resources, Saint Paul, MN.

Moore, V., and six coauthors. 1983. Regional fisheries management investigations. Job Performance Report, Project F-71-R-6, Idaho Department of Fish and Game, Boise, ID.

Mottley, C.M. 1941. The effect of increasing the stock in a lake on the size and condition of rainbow trout. Transactions of the American Fisheries Society 70:414-420.

Nelson, W.C. 1987. Survival and growth of fingerling trout planted in high lakes of Colorado. Technical Publication No. 36, Colorado Division of Wildlife.

Ontario Ministry of Natural Resources. 1982. General guidelines for stocking hatchery fish. Toronto, Ontario.

Pennsylvania Fish Commission. 1987. Management of trout fisheries in Pennsylvania waters. Bureau of Fisheries, Pennsylvania Fish Commission, Harrisburg, PA.

Potter, B.A. and B.A. Barton. 1986. Stocking goals and criteria for restoration and enhancement of cold-water fisheries. Pages 147-159 in R.H. Stroud, editor. Fish culture in fisheries management. American Fisheries Society, Bethesda, MD.

Reininger, B., B. Rieman, and N. Horner. 1983. Cascade Reservoir fisheries investigations. Job Performance Report, Project F-73-R-4, Idaho Department of Fish and Game, Boise, ID.

Smith, M.W. 1968. Fertilization and predator control to increase growth rate and yield of trout in a natural lake. Journal of the Fisheries Research Board of Canada 25:2011-2036.

Smith, S.B., T.G. Halsey, G.E. Stringer, and R.A.H. Sparrow. 1969. The development and initial testing of a rainbow trout stocking formula in British Columbia lakes. Fisheries Management Report No. 60, British Columbia Fisheries Branch, Vancouver, BC, Canada.

Stocek, R.F. and H.R. MacCrimmon. 1965. The co-existence of rainbow trout and largemouth bass in a small Ontario lake. Canadian Fish Culturist 35:37-58.

Stuber, R.J., C. Sealing, and E.P. Bergersen. 1985. Rainbow trout returns from fingerling plantings in Dillon Reservoir, Colorado, 1975-1979. North American Journal of Fisheries Management 5:471-474.

Threinen, C.W. 1959. Cause of mortality of a midsummer plant of rainbow trout in a southern Wisconsin lake, with notes on acclimation and lethal temperatures. Progressive Fish Culturist 20:27-32.

Turner, S.E. 1977. Survival and growth of various sizes of trout stocked in Lake Taneycomo. Final Report, Project F-1-R-25, Missouri Department of Conservation, Jefferson City, MO.

Van Velson, R.C. 1986. Techniques for measuring summer trout habitat in coolwater reservoirs of Colorado. Fishery Information Leaflet No. 38, Colorado Division of Wildlife, Denver, CO.

Welsh, T.L. 1975. Squawfish control in Cascade Reservoir. Job Performance Report, Project F-53-R-10, Idaho Department of Fish and Game, Boise, ID.

A P P E N D I C E S

Appendix A. Stocking of put-and-grow rainbow trout.

Appendix A-1. Put-and-grow rainbow trout stocking guidelines for Michgan waters (from Borgeson 1987).

Lake or stream classification	Expected yield (lb/acre)	Percent survival trout to angler	Average size of trout in catch (lb)	Number and size of trout to stock per acre
Large, oligotrophic multispecies lakes	1-5	20	1-2	2-25 (5-7" yrlg) 10/lb+
Multispecies, two-story (mesotrophic) lakes	5	20	1	25 (5-7" yrlg) 10/lb+
Single-species trout lakes	10-30	20	1	50-150 (3-4" fing) 100/lb

Appendix A-2. Put-and-grow rainbow trout stocking rate (fish/acre) guidelines for Minnesota (from Johnson 1978).

	Expected fishing pressure		
	low[a]	moderate[b]	High[c]
Small fingerlings (>100/lb)			
Northeastern softwater	150	225	300
Northcentral softwater	175	250	350
Hardwater	225	300	400
Hardwater-marl	225	300	400
Bog stain	150	225	300
Shallow, marginal	150	225	300
Frequent winterkill	75	150	300
Medium to large fingerlings (10-100/lb)			
Northeastern softwater	100	150	200
Northcentral softwater	125	175	225
Hardwater	150	200	250
Hardwater-marl	150	200	250
Bog stain	100	150	200
Shallow, marginal	100	150	200
Frequent winterkill	50	100	200
Yearlings (<10/lb)			
Northeastern softwater	50	75	100
Northcentral softwater	65	85	115
Hardwater	75	100	125
Hardwater-marl	75	100	125
Bog stain	50	75	100
Shallow, marginal	50	75	100
Frequent winterkill	25	50	100

[a] less than 100 hours per acre
[b] 100-200 hours per acre
[c] more than 200 hours per acre

Appendix A-3. Put-and-grow rainbow trout stocking guidelines for Ontario (Ontario Ministry of Natural Resources 1982).

Modified OMNR Method (Anon. 1970	Where TDS > 100:	7.0 kg of fish per hectare less than 6 m deep
	Where TDS < 100:	4.5 kg of fish per hectare less than 6 m deep
Modified New York Method (Engstrom-Heg 1979)		
	Stocking Rate (kg/hectare) =	0.94 *VREI*

Appendix A-4. Methods used to calculate stocking rates for put-and-grow trout in Pennsylvania lakes and reservoirs (Pennsylvania Fish Commission 1987).

Step 1. Calculate MEI = ,,/*TDS/mean depth*

Step 2. Estimate Yield as *2 MEI*

Step 3. Adjust yield to standing stock; multiply by constant Kb

_ Kb

3.5 for oligotrophic, no predators
2.0 for mesotrophic, two story, MEI >1.5
1.0 when poor growth and condition observed under Kb = 2.0

Step 4. Calculate stocking rate (number/acre/year) as:

_ Standinq stock
Projected survival

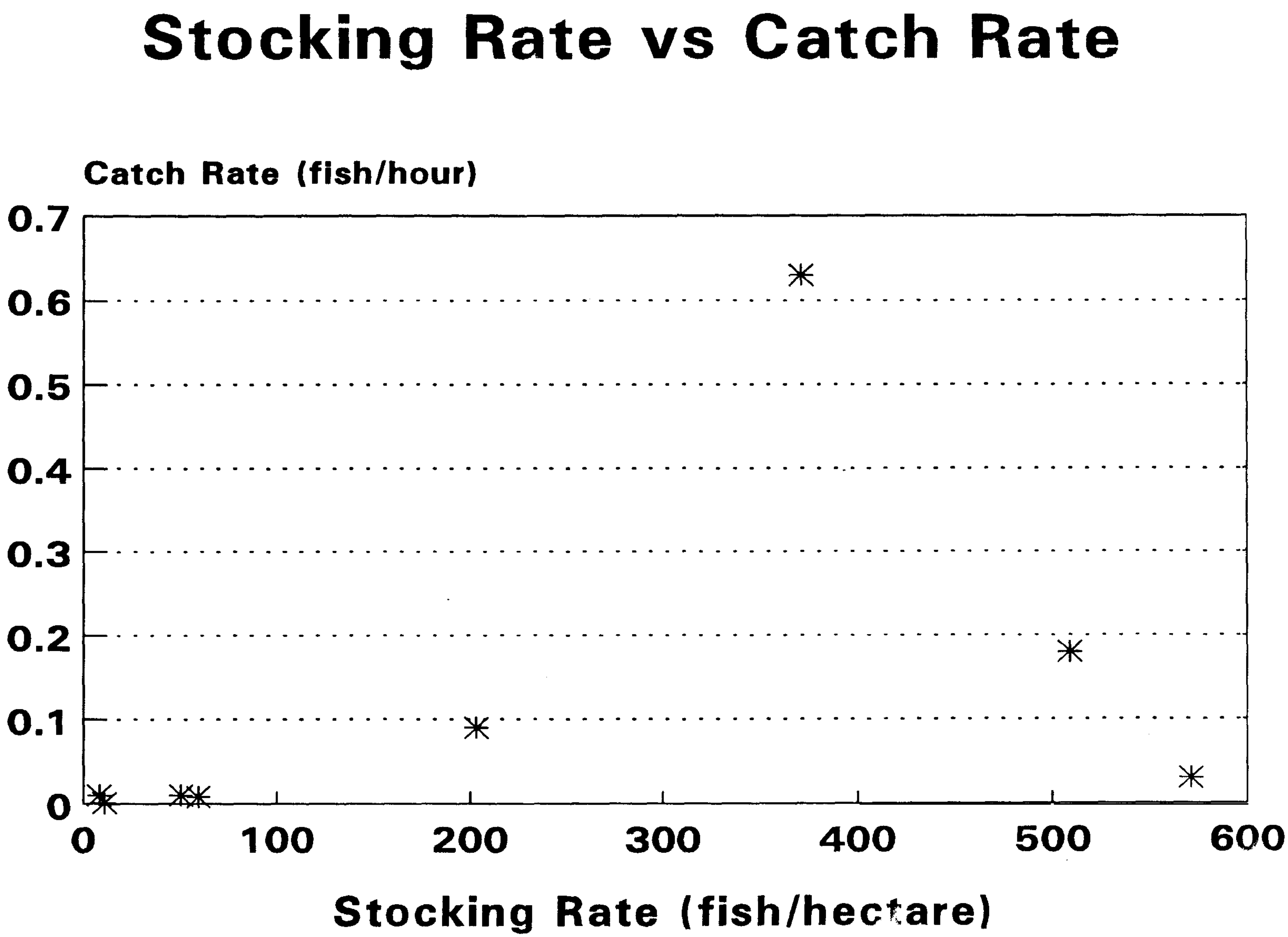
with projected survival = .10 for fish <75 mm
= .15 for 75-100 mm fish
= .20 for 100-150 mm fish

Appendix B. Data summary for past evaluations on put-and-grow rainbow trout waters in Idaho.

Appendix B. Data summary for past evaluations on put-and-grow rainbow trout waters in Idaho.

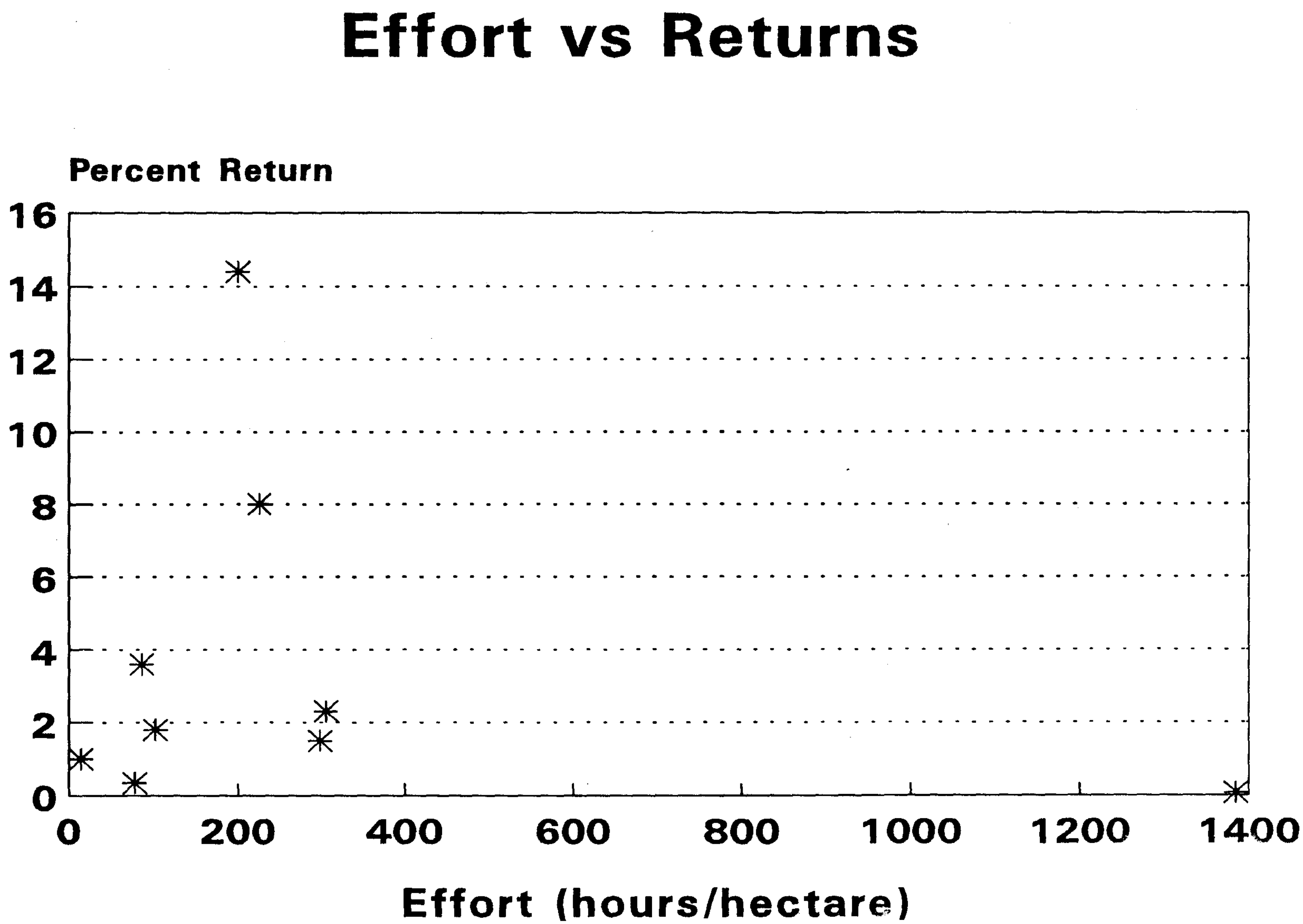
			Previous year	Return rate (%)		Rainbow trout catch rate (fish/hour)			Effort
Water	Year	P&T/hectare	P&G/hectare	P&G	P&T	Total	(hr/hectare)	P&G	P&T
Island Park	1986	20	371	0..63	0.24	0.87	5.3	-	-
Ririe Reservoir	1979	101	331	-	-	0.47	234	-	-
Ririe Reservoir	1982	147	509	0.18	0.24	0.42	226	8	37
Ririe Reservoir	1986	149	291	-	-	0.51	1.02	1.8	29
Ashton	1986	166	125	-	-	-	77.5	0.2-0.5	36-46
Sand Creek Ponds	1986								
Pond 1		700	2,090	-	-	0.38	306	2.3	5.7
Pond 2		288	1,390	-	-	1.0	299	1.5	31.4
Pond 3		127	638	-	-	0.44	86	3.6	12.0
Pond 4		143	321	-	-	0.45	200	14.4	27.6
Mackay Reservoir	1983	9.2	28	-	-	0.45	200	14.4	27.6
Mackay Reservoir	1992	96	203	0.09	0.60	0.78	-	-	-
Magic Reservoir	1982	kO.3	742	-	-	-	-	<1	-
Magic Reservoir	1983	12.0	742	-	-	0.12	98.3	-	-
Magic Reservoir	1984	-	571	0.03	0.24	0.27	-	-	-
Anderson Ranch Res.	1985	41	238	-	-	<0.05	41.4	-	-
Anderson Ranch Res.	1986	0	50	<0.01	-	- -	-	-	-
Cascade Reservoir	1981	5.9	10.6	<0.001	0.01-0.03	<00.05	-	-	-
Cascade	1987	24.4	8.1	0.01	0.14	0.15	33.4	-	-
Cascade Reservoir	1991	12.5	59.1	0.008	0.06	0.12	14.3	1.0	6.5
Winchester Res.	1981	1.117	1.176	-	-	0.64	-	-	-
Winchester Res.	1983	1,388	425	-	-	1.11	-	-	-
Winchester Res.	1984	1,384	1,012	-0	-	0.47	-	-	-
Winchester Res.	1987	1,373	1,071	-	-	0.74	1,311	-	55
Winchester Res.	1988	1,900	1,0071		-	0.79	1,358	0.07	67
Spring Valley Res.	1981	1,480	2,400	-	-	1.58	-	-	-
Spring Valley Res.	1983	1,388	425	-		2.11	-	-	-j
Spring Valley Res.	1987	3,206	2,532	-	-	1.14	1,879	-	38
Spring Valley Res.	1988	2,037	1,415	-	-	0.93	1,874	-	77
Waha Reservoir	1959	218	395	-	-	-	-	6.3	91
Waha Reservoir	1983	654	245		-	1.02	-	-	-
Manns Lake	1981	272	690		-	0.55	-	-	-
Manns Lake	1983	445	445	-	-	0.94	-	-	-
Manns Lake	1987	330	1,138	-	-	1.05	350	-	52
Manna Lake	1988	652	690	-	-	0.80	460	-	41
Soldier Meadows	1958	123	245	-	-	-	-	7.2	48.1
Soldier Meadows	1959	184	175		-	-	-	1.0	43
Moose Creek Res.	1983	718	406		-	1.62	-	-	-

Appendix C. Relationship between put-and-grow rainbow trout stocking rates and catch rates.



Appendix C. Relationship between put-and-grow rainbow trout stocking rates and catch rates.

Appendix D. Relationship between angling effort and percent return of put-and-grow rainbow trout.



Appendix D. Relationship between angling effort and percent return of put-and-grow rainbow trout.

JOB PERFORMANCE REPORT

State of: Idaho Project Name: Put-and-grow Trout Evaluations

No.: F-73-R-15 Title: Put-and-Grow versus Put-and-Take Stocking Experiments

Subproject No.: V

Study No.: III Job: 2

Period Covered: April 1, 1992 to March 31, 1993

ABSTRACT

In 1992, we initiated a project aimed at comparing the relative performance of put-and-grow versus put-and-take trout in 13 lakes and reservoirs statewide. All waters were stocked with both size classes, and fish were marked to identify size and year of planting. We designed creel censuses to monitor the relative contribution to the creel of the different marked groups. Limnological characteristics and species composition were assessed in each water.

Creel census results for evaluations begun in 1992 were limited to spring-stocked put-and-take fish. First-year returns ranged from 6.4% in Spirit Lake to 60.8% in Winder Reservoir, with estimated costs per fish harvested of $8.48 and $.89, respectively.

Data from ongoing evaluations (started before 1992) provide some comparative data on returns of put-and-grow versus put-and-take trout. Returns of put-and-grow trout ranged from 0.014% for 150-175 mm fish in Cascade Reservoir to 22.9% for 200 mm fish in C.J. Strike Reservoir. . Costs per fish harvested were estimated at $478.00 and $.69, respectively.

Growth of spring-planted put-and-take fish was assessed in five waters. Growth ranged from 0.30 mm/day in Little Wood Reservoir to 1.12 mm/day in Springfield Lake.

We will continue to monitor these fisheries through 1994 to describe cost-effectiveness of put-and-grow and put-and-take trout stocking programs in different lake and reservoir types. The information will be used to develop stocking guidelines for put-and-grow trout.

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INTRODUCTION

Most of Idaho's lake and reservoir rainbow trout Oncorhynchus mykiss fisheries are supported by plants of put-and-grow and put-and-take hatchery fish. Success of individual stocking programs are evaluated through creel checks ranging from unstructured spot checks to full censuses. With few exceptions, past creel surveys have not differentiated the relative contribution to the fishery of put-and-grow versus put-and-take rainbow trout (Job 1, this report). Consequently, we have very little data on which to judge the relative effectiveness of the two stocking strategies.

Stocking evaluations are a routine part of our fishery management activities, with several recent and ongoing censuses on waters with both put-and-grow and put-and-take rainbow trout. In general, these evaluations are more comprehensive than earlier efforts, and will yield better information on relative contribution and cost to the creel. While this will help us optimize stocking efficiency in individual waters, we still lack statewide perspective of when and where put-and-grow rainbow trout are a cost effective management option. Such perspective can be gained only by describing on a broad scale the factors affecting survival, growth, and return-to-creel.

Stocking requests (species, number, and size of fish) for individual waters are currently established by regional fishery managers, often in concert with local conservation officers. Requests may be based on actual data from stocking evaluations (e.g. catch rates, returns), our best guess, or maintenance of past stocking strategies. Guidelines for successful put-and-take programs call for 40% return to creel (by numbers); for put-and-grow stocking, the target is 100% return by weight. No standardized approach to determine appropriate stocking rates is available, however.

Because we lack specific stocking guidelines, past stocking rates for put-and-grow rainbow trout have ranged from a few fish to over 1,900 fish/hectare statewide (Job 1, this report). Existing stocking guidelines from other states suggest maximum stocking rates of about 620 fish/hectare, but it is unclear how applicable these guidelines are to Idaho waters. Data currently available for Idaho put-and-grow fisheries are insufficient to develop our own guidelines.

Probably the most important reason we have a poor understanding of put-and-grow trout stocking strategies and management is the lack of standardized evaluation methods. Numerous stocking experiments have been conducted in Idaho to evaluate the performance of various strains and sizes of rainbow trout (e.g. Keating 1961; Reininger et al. 1983; Maiolie 1987; Janssen and Anderson 1993). While these studies have often refined stocking strategies for individual waters, the methods used and data collected varied with the goals and objectives of each study. Hence, there is little comparative data available across many waters. Standardizing methods for future evaluations would provide better comparative data and allow clearer interpretation of the factors affecting fish survival, growth and fishery quality.

This report documents the preliminary design and progress made in the first year of the put-and-grow hatchery trout evaluation project. A portion of this project is designed to describe the benefits of put-and-grow versus put-and-take management in lakes and reservoirs statewide, and to develop a standardized put-and-grow evaluation program. It will be useful to describe the influence of lake and reservoir characteristics on performance of put-and-grow fish. Describing relationships among trout growth and returns, stocking rates, catch rates, lake productivity, and presence of competitors or predators will help us develop stocking criteria and guidelines for individual waters. This project is scheduled to investigate the relative performance of put-and-grow versus put-and-take rainbow trout in a variety of waters for at least 2 years.

OBJECTIVES

The management goal of this project is to maximize the efficiency of trout stocking programs in Idaho lakes and reservoirs.

1. To describe the tradeoffs of put-and-grow versus put-and-take management by designing experiments to assess relative performance and cost to the creel under varied conditions.

2. To develop a statewide perspective and guidelines on where to use the two stocking strategies, including appropriate stocking rates, sizes, and timing to maximize efficiency.

3. To develop standardized methods to evaluate put-and-grow stocking programs.

METHODS

Stocking

The approach to this study is to stock differentially marked put-and-grow and put-and-take fish into a wide variety of waters and monitor subsequent growth and contribution to the creel. We included 13 study waters (Figure 1) that represent a wide range of conditions (productivity and species composition). Of these evaluations, four are being conducted by management, with the rest monitored by both research and management personnel. Stocking rates and sizes varied according to management strategies for individual waters. All study waters were stocked with put-and-take rainbow trout. Put-and-grow fish were stocked in the spring, in the fall, or both.

We estimated mean size at stocking by measuring total length (millimeter) of 100 fish prior to release. In several instances, mean length was approximated from pounds counts. In most waters, all put-and-take fish were marked by adipose clips or maxillary clips. Put-and-grow fish were marked only when we needed to differentiate between spring and fall releases, or to identify different strains stocked at the same time. In C.J. Strike Reservoir, we used ventral clips to identify different plants of put-and-grow fish, but not all fish in each plant were marked.

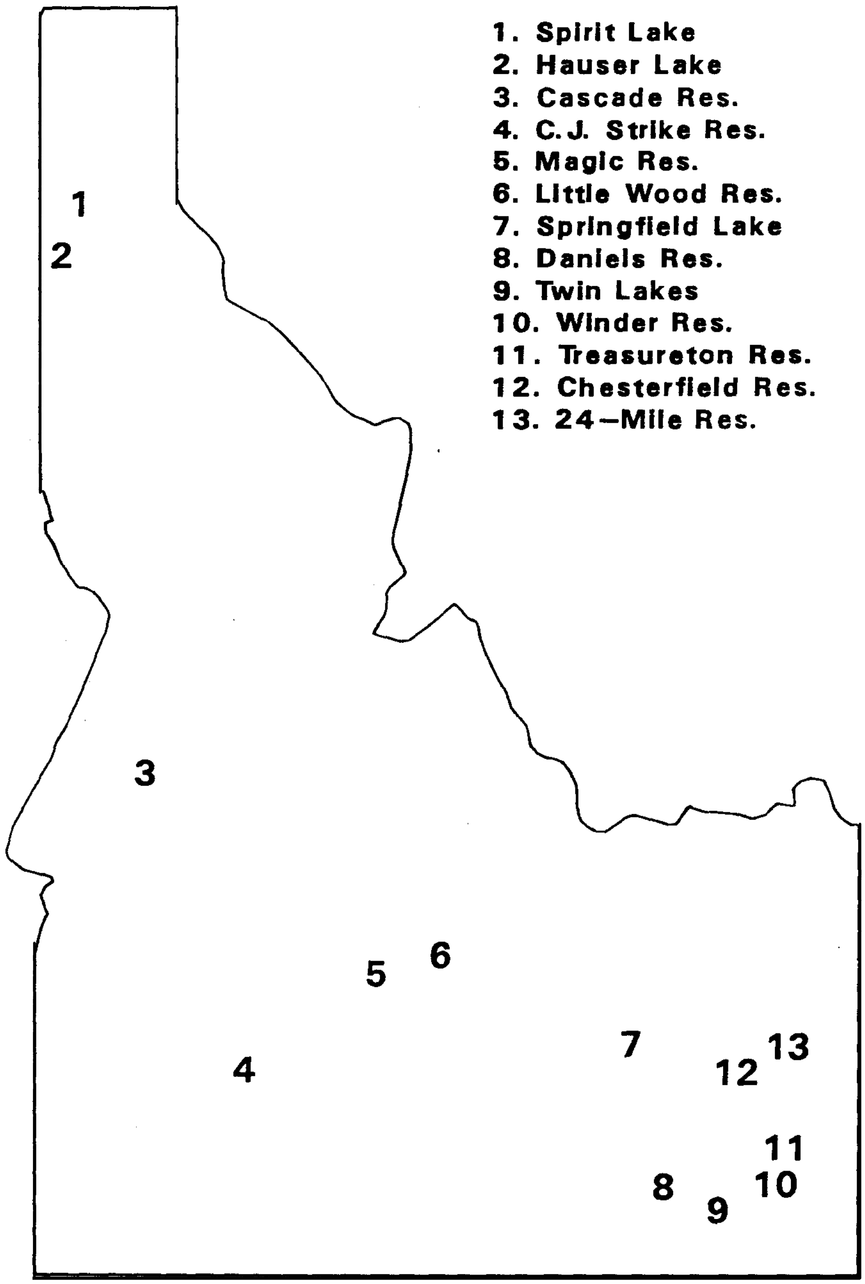

Figure 1. Locations of study waters for put-and-grow versus put-and-take stocking experiments.

We rated the condition of fish at planting for some waters using the pyloric fat index (PFI)(Goede 1987). A minimum of 30 fish were anesthetized and eviscerated at the hatchery. Indices for individual fish were visually estimated as:

0 - no fat apparent on the pyloric cecae
1 - <50% of the pyloric cecae covered with fat
2 - 50% covered
3 - >50% but less than 100% covered
4 - 100% of the cecae covered with fat

We used the mean of the individual PFIs to represent the average condition of the fish at planting.

Contribution to the Creel

Most study waters received only spring put-and-take and fall put-and-grow rainbow trout, while some received both spring and fall put-and-grow fish. Complete randomized creel censuses were developed for each fishery to monitor relative catch rates, returns and contribution to the creel of marked groups. Creel clerks were instructed to check individual fish for marks and record lengths of any marked fish harvested. For the evaluation started in 1992, some spring-planted put-and-grow fish showed up in the creel by fall of 1992, but at least one more year of censuses will be required to assess relative returns, etc. Additional returns of 1992 put-and-take fish and fall planted put-and-grow fish will also be monitored with creel censuses in 1993.

For 1992 put-and-take fish, we used return estimates from the creel census data and hatchery rearing and planting costs to estimate cost per fish harvested in each study water. Production and transport costs for put-and-take rainbow trout vary greatly from one hatchery to another (Appendix A). We calculated both standardized and true costs to the creel. Standardized costs were based on an average cost to raise one put-and-take rainbow trout in Idaho Department of Fish and Game (IDFG) hatcheries ($0.54; Appendix A). To estimate true cost to the creel, we used the cost to rear and plant put-and-take fish for the particular hatchery providing the fish.

Growth and Condition

In seven of the study waters, we used fall gillnetting and electrofishing to sample spring put-and-take fish that had been in the waters for one growing season (about 6 months). We measured and weighed all marked fish captured. We estimated average growth by comparing lengths at stocking to the fall sample means. Growth was expressed as millimeter per day.

Lake Characteristics

To describe the influence of lake characteristics on growth and survival of stocked fish, we worked with the lake and reservoir inventory project to collect basic limnological-data on each study water in 1992. Data included were:

1. Total phosphorous
2. Alkalinity
3. Total dissolved solids
4. Chlorophyll a
5. Conductivity
6. Temperature and oxygen profiles
7. Secchi disk transparency
8. Zooplankton species composition and size structure.

Methods are reported in detail in Dillinger (1993).

To describe fish community influences on trout survival and growth, we compiled information on species composition in each study water. Data were taken from existing IDFG reports or files, or were obtained through personal communications with regional fisheries personnel.

Analysis

Because the new experiments were just initiated in 1992, I made no attempt to quantitatively analyze the data collected. A complete analysis will be performed after we monitor the performance of both put-and-grow and put-and-take rainbow trout in the fisheries through 1994.

RESULTS

Stocking

The 1992 rainbow trout stocking data for each evaluation water are presented in Table 1. Strains, sizes, and timing of plants varied according to management programs on individual waters.

Contribution to the Creel

Chesterfield and Treasureton reservoirs were nearly completely drained during the 1992 season, and in Springfield Reservoir, the creel census did not begin until July. These waters are not included in the results cited below.

Table 1. 1992 Creel census data on waters with put-and-take (P&T)/put-and-grow (P&G) experiments.

Water	Census period	Number of put-and-take trout stocked	Number of marked put-and grow trout planted[a]	Total effort (hr/hectare)	Catch rate (fish/hour)		Harvest		Return by number		Actual cost/fish creeled ($)		Standardized cost/fish creeled (E)	
					P&G	P&T	P&G	P&T	P&G	P&T	P&G	P&T	P&G	P&T
Magic Reservoir	Jun-Dec	33,8500	201,400 (s)	300	-	0.15	-	9,363	-	27.6	-	0.69	-	1.96
Little Wood Res.	June-Dec	7,600	54,000 (s)	250	-	0.18	-	2,400	-	31.5	-	1.78	-	1.71
Twin Lakes	May-Sep	11,150	-	84	-	0.09	-	1,446	-	12.9	-	2.79	-	4.19
Winder Reservoir	May-Sep	13,160	-	547	-	0.51	-	7,997	-	69.8	-	0.59	-	0.89
Treasureton Res.[b]	May-Aug	16,000	-	350	-	0.68	-	5,823	-	36.4	-	0.99	-	1.48
Springfield Lake[c]	Jul-Sep	8,500	-	129	-	0.11	-	747	-	8.9	-	3.26	-	6.07
Chesterfield Res.[b]	May-Jun	40,000		35	-	0.13	-	1,430	-	3.6	-	5.28	-	15.00
C.J. Strike Res.	Apr '92-May	0	26,390 (w)	78	0.003	-	343	-	1.3	-	3.06	-	4.62	-
			7,875 (s)	78	0.017	-	1,802	-	22.9	-	0.69	-	0.66	-
Cascade Res.[d]	Nov '90-Nov	150,000		17		0.14.		31,500		21.0		2.53		3.42
			169,000 (f)		<0.01		655		0.38		18.06			-
			145,000 (s)		<0.01		1,094		0.75		9.19			-
			130,000 (f)		<0.01		298		0.23		30.54			-
			396,000 (f)		<0.01		58		0.01		478.00			-
Spirit Lake	Apr-Sep	7,000	0	54	-	0.015	-	448	-	6.4	-	30.16	-	8.48
Hauser Lake	Apr-Sep	9,000	-	140	-	0.06	-	2,004	-	22.3	-	8.65	-	2.48

[a] Includes only marked fish stocked in spring (s), fall (f), or winter (w).
[b] Reservoirs went dry.
[c] Census not started until July; effort, harvest, and returns were underestimated.
[d] The several groups of put-and-grow trout were part of strain/size evaluation.

Creel census results from ongoing evaluations (started before 1992) provided some preliminary data on comparative returns of put-and-grow and put-and-take fish (Table 1). Estimated returns for put-and-grow fish ranged from .014% for 150-175 mm fish in Cascade Reservoir to 22.9% for 200 mm fish in C.J. Strike Reservoir. Returns for put-and-take fish ranged from 6.4% in Spirit Lake to 60.8% in Winder Reservoir.

Costs of put-and-grow rainbow trout in the creel ranged from $.69 per fish for 200 mm fish in C.J. Strike Reservoir to $478.32 per fish for one Cascade Reservoir plant (Table 1). Within Cascade, four different put-and-grow rainbow trout plants (sizes 75-200 mm) ranged in cost from $9.19 to $478 per fish harvested.

Standardized cost per fish in the creel for put-and-take fish ranged from $0.89 in Winder Reservoir to $8.48 in Spirit Lake (Table 1). Estimated true costs ranged from $.59 in Winder Reservoir to $30.16 in Spirit Lake.

<u>Growth and Condition</u>

In the five waters sampled in fall, growth of 1992 spring put-and-take fish ranged from 0.30 mm/day in Little Wood Reservoir to 1.12 mm/day in Springfield Reservoir (Table 2). Mean pyloric fat indices for fall sampled fish ranged from 0.1 in Little Wood Reservoir to 3.2 in Springfield Reservoir.

<u>Lake Characteristics</u>

Limnological data and species composition for each evaluation water sampled in 1992 are presented in Appendix B. Due to continued drought conditions many of the Southern Idaho reservoirs-were at or near historic low water levels in 1992. Chesterfield and Treasureton reservoirs were almost completely drained. The limnology data collected does not represent "average" conditions in these reservoirs, only the conditions under which the 1992 plants had to survive.

DISCUSSION

On most of the study waters, this was the first year of what will be a long-term evaluation program. Seven additional waters are scheduled to be included in the program in 1993. The broad-based approach should be a powerful tool to examine the factors influencing performance and contribution to the creel of put-and-grow versus put-and-take trout in lakes and reservoirs statewide. Results from the evaluations will help us determine which sizes to plant and also describe expected returns and costs in various lake types. This will standardize our approach to stocking strategies, which have been highly variable in the past.

Information on cost per fish or kilogram harvested can be an educational tool to explain changes in management programs to the public. For example, in

Table 2. Mean growth rate (milimeter per day) and pyloric fat index (PFI) of put-and-take rainbow trout six months after stocking in five Idaho waters, 1992.

Water	Growth Rate (mm/day)	PFI
Little Wood Reservoir	0.30	0.1
Twin Lakes	0.41	0.3
Daniels Reservoir	0.69	1.4
Magic Reservoir	0.74	1.1
Springfield Lake	1.12	3.2

J2 T2

Cascade Reservoir return-to-creel of smaller fish was clearly uneconomical. The average return rate of 840,000 smaller (125-200 mm) put-and-grow fish was 0.25%. Stocking costs totaled about $58,800. Average cost per fish harvested was thus $27.90. Larger (250 mm) put-and-grow fish returned at 21%. Cost per larger fish harvested was $1.90. At that return rate, stocking 10,000 larger fish would provide the same harvest as the 840,000 smaller fish at a cost of about $4,000. Savings achieved by releasing larger fish would be almost $55,000.

In trophy hatchery trout fisheries (20-in minimum length) where yield and returns are less important, cost effectiveness of stocking should be based on other criteria. Because social benefits of trophy regulations are difficult to define, the most straightforward approach to compare stocking strategies may be to assess cost per angler hour generated or cost per fish caught and released.

Another long-term objective of this project, not addressed in this report, is to develop a standardized program for put-and-grow evaluations. Periodic monitoring is important to refine stocking strategies, or to assess the success of new programs (Ontario Ministry of Natural Resources 1982). With no standardized approach in the past, experimental design and methods varied widely, and data collected were often not comparable across waters. In the next year we will use information and experience gathered from the new evaluations to propose a standardized evaluation program for statewide use.

Hatchery evaluation programs are expensive. The cost of a comprehensive evaluation may exceed the cost of stocking in a particular lake. This is where the broad-based approach is most important. If we can describe with some confidence the lake characteristics conducive to put-and-grow management, and also prescribe reasonable bounds for stocking rates, we will have less need to repeatedly assess individual stocking programs. Changes in stocking strategies (e.g. experimental strains) should, however, be accompanied by a full evaluation to assess costs and benefits.

RECOMMENDATIONS

1. In basic yield fisheries use costs per fish or weight harvested to determine the most cost-effective size at planting.

2. In trophy hatchery trout fisheries, use cost per angler hour generated or other non-harvest criteria to assess cost-effectiveness of planting strategies.

3. Use cost-effectiveness information where appropriate to explain changes in stocking programs to the public.

4. Continue to monitor the limnological conditions and growth and returns of put-and-take and put-and-grow rainbow trout in each study water for 2 years after experimental plantings. Coordinate with the regions for data collection.

5. Increase the number of study waters from 13 to 20 in 1993.

A P P E N D I C E S

Appendix A. Costs to rear and stock put-and-take rainbow trout at IDFG hatcheries, 1992 (IDFG unpublished data).

Hatchery	Number of Fish	Cost	Cost per fish
Hagerman	950,575	182,097	0.19
American Falls	110,600	33,139	0.29
Grace	100,050	35,749	0.36
Nampa	226,100	109,397	0.48
Hayspur	142,250	79,475	0.56
Clearwater	152,500	116,643	0.76
McCall	35,048	29,896	0.85
Mullan	54,050	47,086	0.87
Mackay	105,900	127,662	1.20
Ashton	58,800	78,488	1.33
Clark Fork	149,900	289,979	1.93
	2,085,773	1,129,656	0.54

J2_APA

Appendix B. Select limnological data and species composition for put-and-grow/put-and-take trout evaluation waters, 1992.

Location	Conductivity (mmhos)	Spring secchi disk transparency (m)	Species Composition[a]
Magic Reservoir	270	2.4-3.9	WRB, YEP, SU, SMB, RSS
Little Wood Res.	270-300	1.3-4.7	WRB, SU
Daniels Reservoir	520	4.0-5.1	LCT, HYB
24-Mile Reservoir	725	-	MTS, BKT
Twin Lakes	304	2.9-4.8	LMB, BLG, GSF
Winder Reservoir	253	4.0-4.1	LMB, BLG, GSF
Treasureton Res.	525	2.4	CYP
Springfield Lake	610	-	UTS, SU, BRT
Chesterfield Res.	480	4.9	BRT
C.J. Strike Res.	590-680	0.7-1.8	BLG, LMB, SMB, PMS, YET, BCR, SQF, RSS, SU, CAR, CHS, BBH, CCF
Cascade Reservoir	420-438	0.7-1.7	YEP, COH, SMB, SQF, SU, KOK, BBH, MWF
Spirit Lake	20	4.2	KOK, LMB, PMS, YEP, NOP, CT, BCR, PWF
Hauser Lake	45	5.2	PMS, YEP, BCR, BBH, TEN, LMB

[a] Species other than hatchery rainbow trout; WRB - wild rainbow trout, YEP yellow perch, SU = unidentified sucker app., SMB = smallmouth bass, RSS = redside shiners, LCT = Lahontan cutthroat, HYB rainbow x cutthroat hybrids, MTS = mountain sucker, CAR = carp, LMB = largemouth bass, TIM = tiger musky, BLG = bluegill, BBH = brown bullhead, GSF = green sunfish, CYP = unidentified cyprinid, UTC = Utah chub, BRT = brown trout, BKT = brook trout, PMS = pumpkinseed, BCR = black crappie, SQF = northern squawfish, CHS = chiselmouth chub, CCF = channel catfish, COH = coho salmon, KOK = kokanee salmon, MWF = mountain whitefish, NOP = northern pike, CT = westslope cutthroat, PWF = pygmy whitefish, TEN = tench.

JOB PERFORMANCE REPORT

State of: Idaho Project

No.: F-73-R-15

Subproject No.: V

Study No.: III

Name: Put-and-grow Trout Evaluations

Title: Hatchery Capabilities

Job: 3

Period Covered: April 1, 1992 to March 31, 1993

ABSTRACT

We used hatchery records to describe the statewide rainbow trout production capabilities of our resident hatcheries. From 1982 to 1991, production averaged 1.08 million lb and 8.22 million fish. Total weight produced has remained fairly stable while numbers are increasing,. due to a recent increase in put-and-grow trout production. From 1988 to 1991 put-and-grow rainbow trout increased from 6% to 27% of the weight produced.

Production tradeoffs between put-and-grow and put-and-take rainbow trout are difficult to quantify. Estimates of hatchery production under various scenarios are needed so statewide production capabilities for different sizes of trout are better defined.

We compared 1990 requests for hatchery fish to actual stocking records for 76 put-and-take requests and 62 put-and-grow requests. Put-and-take requests were met completely in 22% of the waters while put-and-grow requests were met completely in 5% of the waters. The records we used did not reflect undocumented changes in requests, or local conditions which precluded planting. A more realistic long-term request process to help plan and prioritize hatchery fish production is needed. Continued emphasis on broodstock development is needed to decrease our dependence on unreliable out-of-state egg sources and help stabilize production.

Fishery managers incur no costs to stock fish, thus incentives to maximize stocking efficiency are *absent.* We should investigate administrative methods to provide these incentives. One alternative is to allocate annual hatchery production to regions based on fishing effort. Another approach would be to redistribute to the regions any long-term dollar savings as a result of improved stocking efficiency and decreased hatchery costs.

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INTRODUCTION

The Idaho Department of Fish and Game (IDFG) resident fish hatcheries annually stock over 1 million lb of rainbow trout Oncorhynchus mykiss in the streams, lakes and reservoirs of the state. Our resident hatchery budget ($2 million) represents 20% of the total annual fisheries budget of $10-12 million. Because of the cost of the program, improving the effectiveness and efficiency of our hatchery system has become an important priority.

Biologists have expressed concern that the hatchery system often fails to provide the numbers, strains, and sizes of fish requested. Inconsistencies in the type and quality of stocked fish may make it difficult to effectively manage hatchery trout fisheries. Many of these shortfalls are unavoidable under the current system. Reliance on out-of-state egg sources, disease, and water quality problems and budget constraints, among other factors, affect the number, type and quality of fish that can be raised at a given hatchery.

Requests for stocking (species, size, timing) are developed annually for individual waters by regional fishery managers, and often change considerably from year-to-year. Recent drought has reduced demand for stocking in reservoirs. Major changes in stocking programs also frequently follow turnover in management personnel.

Hatcheries typically receive stocking requests 11-12 months prior to planting. Because most of our egg sources are external, this provides little lead time for hatcheries to order eggs and establish production goals, especially for put-and-take fish which may require over a year to reach catchable size.

In general, we have a poor understanding of the production potential of the hatchery system or the costs of hatchery fish. Requests may exceed what can reasonably be produced, or request (in numbers) may be met at the sacrifice of quality (size and condition). Alternatively, our hatcheries may be trying to do too much by providing the wide variety of species, strains and sizes of fish included in management requests.

Describing the administrative portion of the hatchery trout request process, along with the production capabilities and limitations, would help us improve the hatchery trout program. Improving the efficiency of the hatchery program itself, plus developing stocking strategies to increase returns could represent a considerable economic benefit to IDFG.

OBJECTIVES

The management goal of this project is to improve efficiency in the hatchery trout request process.

1. To characterize the statewide production capabilities of our hatcheries and identify tradeoffs from rearing put-and-grow (spring and fall) versus put-and-take fish.

2. To compare 1990 stocking requests to hatchery stocking records; identify shortfalls and reasons for discrepancies.

3. To identify limitations to hatchery fish production in Idaho.

METHODS

Production Capabilities

Production potential of our hatcheries will change with the species, strains, and sizes of fish raised. To describe potential production, we summarized production records for individual hatcheries from 1982-91. We focused on rainbow trout because it accounts for the majority (65-70%) of the resident hatchery production costs. Where possible, we separated out catchable from subcatchable fish in the records, and summarized production by weight and numbers of fish. We summed the average production per facility to estimate statewide production potential.

We met with hatchery superintendents and state hatchery managers to discuss the limitations to production at individual facilities. We also. reviewed available literature on hatchery programs in other states and provinces to gain insight into alternative management strategies for our own program.

Requests Versus Stocking

We compared the 1990 hatchery requests to actual stocking records for 1990, using the computerized database maintained in the Fisheries Bureau of IDFG. To simplify the comparisons, we considered only waters where more than 10,000 total fish were stocked. These larger waters received about 55% of the nearly 30 million fry, fingerling, and catchable fish stocked in 1990. We compared requests and stocking for put-and-take and put-and-grow fish separately, and made comparisons in the following categories:

1. Were all <u>species and strains</u> in the request stocked (regardless of numbers and size)?

2. Did the <u>total number</u> of fish stocked meet the total number in requests?

3. Did the <u>sizes</u> of all species and strains stocked meet or exceed the sizes requested?

4. Were all fish stocked on the <u>date(s)</u> requested?

5. Did the <u>number stocked of each species and strain</u> meet or exceed the number requested?

6. Did the water receive <u>extra species or strains</u> not included in requests?

7. Did the water receive extra numbers of the species or strains requested?

8. Were all criteria in requests met? (This excludes the extra species and strains and extra numbers categories.)

We allowed some leeway in numbers (±5%) and sizes (+0.5 in) without considering the plant as failing to meet requests. Most requests for date of planting were by month, and any plant outside the requested month (even by a few days) was given a failure mark.

For both put-and-grow and put-and-take requests, we summarized the results to describe the percentage of each request category met by hatcheries. We submitted the results to individual hatchery managers for feedback on the methods used, and to provide explanations for failures to meet specific requests.

RESULTS

Production Capabilities

In general, annual hatchery rainbow trout production has been stable for the last decade. Production for 1982-91 averaged 1.08 million lb and 8.22 million fish (Figure 1, Appendix A).

Total numbers produced shows a slight increasing trend, while total weight produced does not. This reflects an increase in put-and-grow rainbow trout production, especially since 1988 (Figure 2, Appendix B). From 1988 to 1991 put-and-grow production increased from 6% to 27% of the total weight of rainbow trout produced. In 1990 and 1991, put-and-grow costs represented 33-38% of the total rainbow trout production costs (Appendix B).

With our current facilities, we can probably consistently produce about 1 million lb of rainbow trout annually. Fall fingerling production does not interfere with catchable production at the larger facilities (Hagerman and Nampa); most fall fingerling eggs are received in spring as catchables are being stocked and do not occupy hatchery space required for catchables. Spring fingerling production reduces catchable production directly. Eggs for spring fingerlings are usually received in the fall and fish must be overwintered in addition to the next year's catchables.

Reducing fall fingerling production would not substantially increase the potential for catchable production at most of our facilities. The exception would be at hatcheries where water temperatures limit growth, and the rearing cycle for catchables is more than one year. In this case, raising fingerlings over the summer would decrease catchable production. Most of our hatcheries with low temperatures, however, grow relatively few or no fall fingerlings.

Although the tradeoffs for spring fingerlings versus catchables are more direct, they are still difficult to quantify. Tradeoffs are not on a pound-for-pound basis. Fingerlings, by weight, have higher maintenance and transport costs

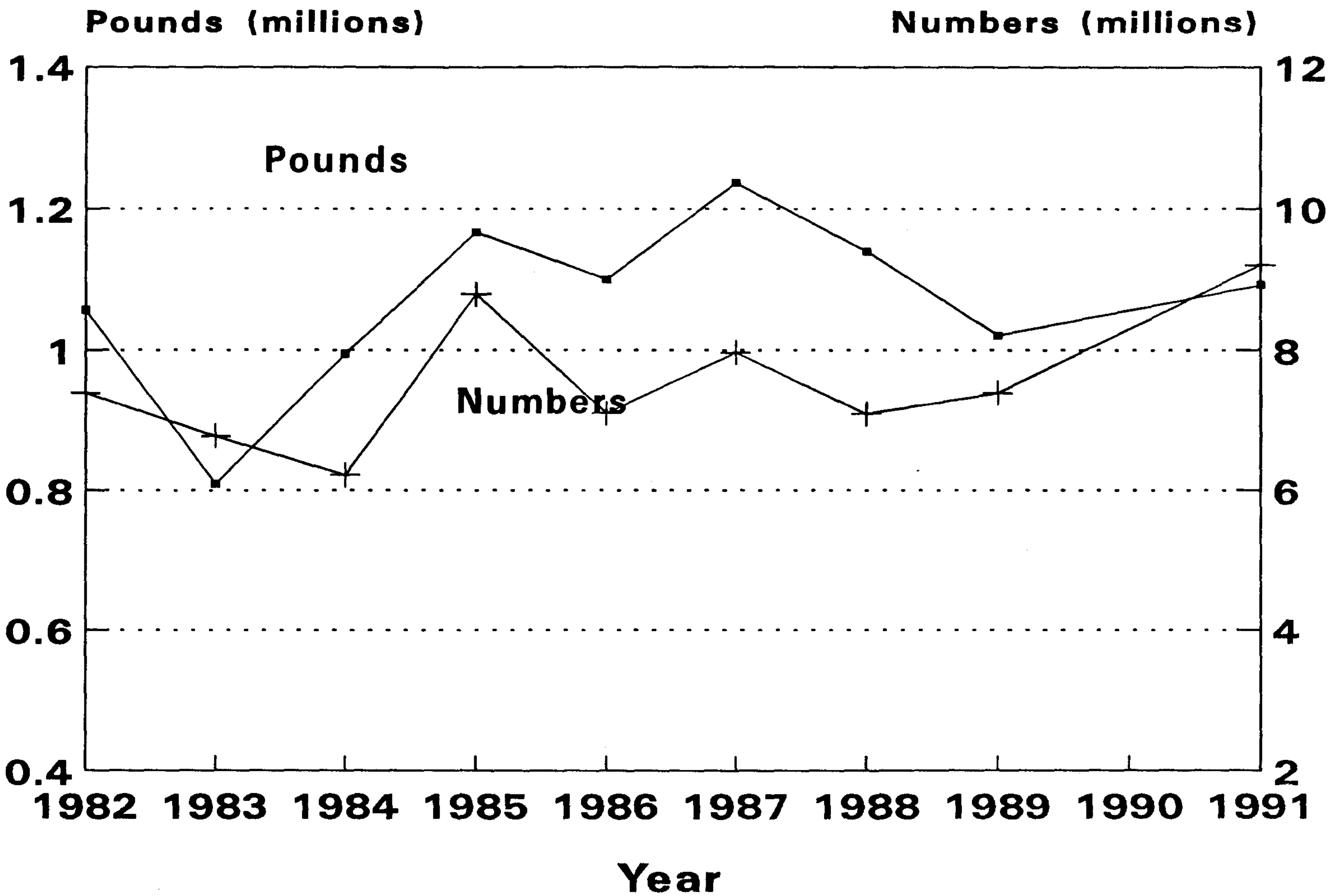

Figure 1. Production (pounds and numbers) of rainbow trout in IDFG resident hatcheries, 1982-1991.

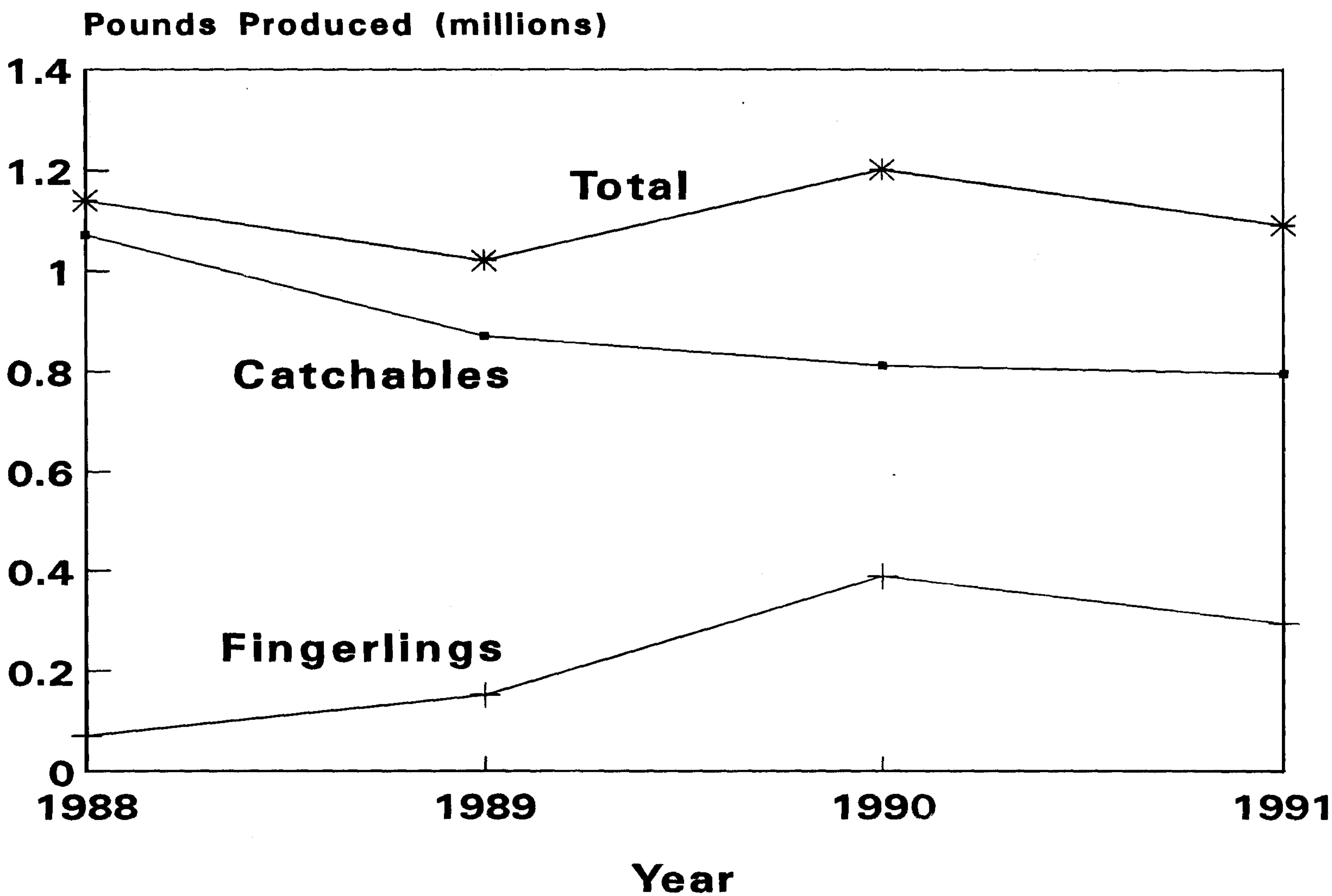

Figure 2. 1988-1991 fingerling and catchable rainbow trout production (pounds) at IDFG resident hatcheries.

than catchables. Hatcheries can generally rear about 40-50% more catchable-size fish (by weight) than 4-in fish in a given raceway (Mike Larkin, personal communication). In other words, reducing spring fingerling production by 1,000 lb could increase catchable production by about 1,500 lb. This is **a** very simplistic approach, however. Differences in rearing conditions among hatcheries, and year-to-year differences in egg supply and timing, mean that the production tradeoffs will vary with the facility and the year.

Requests Versus Stocking

We summarized records for 76 put-and-take requests and 62 put-and-grow requests for 1990 (Table 1, Appendix C). Based on the available records, put-and-take requests were met completely in 22% of the waters while put-and-grow requests were met completely in only 5% of the waters. The largest problem area was for stocking date (month) for both size categories (Table 1, Appendix C).

For the put-and-take comparisons, 22% of the waters received species or strains not included in requests, and 46% received more fish (of requested species/strains) than requested (Table 1, Appendix C). For the put-and-grow comparisons, 44% of the waters received unrequested species or strains, while 56% received more fish than requested.

Feedback from the hatchery managers indicated that the records we used to make comparisons were not always valid. The two most common explanations for not meeting requests were undocumented changes in requests and errors in the planting records (Table 2). On occasion, high water temperatures at stocking sites led to later stocking dates than requested. Loss or reduction in egg sources also was important. Substitute species or strains were commonly used to replace requested stocks that were unavailable.

DISCUSSION

While it is fairly straightforward to describe average rainbow trout production (1.08 million lb) in our hatcheries, it is difficult to define production potential for different sizes of fish. Obviously, by decreasing catchable production we could significantly increase fingerling production (numbers). However, given the past variability in egg sources and timing, and hatchery-to-hatchery differences in production costs, absolute tradeoffs are impossible to describe using current production records. Year to year differences in water quality and quantity and disease and predation losses also affect production at each facility. Despite these limitations, we can make some conclusions with the available information.

Fall fingerling production has little influence on our ability to raise catchables because spring stocking of catchables creates hatchery space to rear them. Spring fingerlings, because we rear them over the winter, compete directly with catchables for hatchery space. Thus, we sacrifice more catchables for spring fingerlings than for fall fingerlings. Describing that tradeoff in terms

Table 1. Results of requests versus stocking comparison for select Idaho waters, 1990.

	Category	Percentage of requests met
Put-and-take (n = 76)		
	Number	66
	Size	71
	Species/strain	96
	Date	39
	Species/numbers	58
	Extra species/strains	22
	Extra numbers	46
	Total request met	22
Put-and-grow (n = 62)		
	Number	58
	Size	34
	Species/strain	58
	Date	32
	Species/numbers	34
	Extra species/strains	44
	Extra numbers	56
	Total request met	5

J3_T1

Table 2. Explanations given by resident hatchery managers for failing to meet stocking requests.

Explanations
– Undocumented changes in requests.
– Planting records were wrong.
– Receiving water too warm for planting on requested date.
– Substitute strains were used to make up for shortages in requested strains.
– Requests were unrealistic (e.g., 6" Pennask rainbow trout in May)
– Unanticipated disease or predation losses at hatcheries.
– Loss or shortage of requested egg sources.
– Low water levels precluded planting.

J3_T2

of numbers or pounds is difficult, especially given the variability in egg sources. Because most of our larger hatcheries rear both size classes, past production records are not useful to describe potential catchable production if fingerlings were dropped.

Regardless of the difficulties, it would be a useful exercise to estimate potential production at each facility under several scenarios. For example, the 1982-91 annual rainbow trout production at Hagerman National Fish Hatchery averaged about 400,000 lbs (Appendix A). If we assume stable eggs sources and receiving dates, what is the maximum total production if only catchables were reared, if 20% of production were spring fingerlings, or with 20% spring and 20% fall fingerlings? Hatchery managers should be able to estimate production tradeoffs under a given set of assumptions. Even rough estimates would be useful, and could help define the number versus size tradeoffs for management biologists and for the public.

Our comparisons of 1990 requests and actual stocking records had some important limitations. Many requests are changed considerably after the initial request process. Adjustments in stocking were often made by telephone or memorandum, and were poorly documented. They did not show up on the computer records we used. Adjustments in stocking were most often made because the requested species or strains were not available, or because of low water conditions due to drought.

Regardless of the limitations, it is clear that most requests for hatchery fish are either not met or are changed prior to stocking. Flexibility in stocking requests is necessary, but actual stocking rarely matches requests completely. It is unclear how this affects management success on individual waters. Many of our fishery managers feel the inconsistency in hatchery trout production (in terms of stocks and strains) makes it difficult to effectively manage hatchery trout fisheries.

Providing more consistent hatchery products could help standardize stocking programs. Most of our hatchery limitations are external in nature, the most important being heavy reliance on out-of-state egg sources. Eggs are often obtained through a bidding process, and the vendors (along with the strains of fish obtained) may change each year. We are currently expanding production from our in-state broodstocks. Continuing this expansion and developing new broodstocks would decrease our dependence on external egg sources.

Defining production capabilities and stabilizing hatchery production will not necessarily improve efficiency of the program. It is equally important to develop stocking guidelines for individual waters. Standardized stocking programs would help us predict demand and plan for hatchery fish production. While this may be desirable, it will not be practical unless hatchery products are consistent in size and quality.

Other states and provinces have addressed the problems of hatchery program management and prioritizing hatchery fish production. Several suggest that broodstock development and long-term production plans are important to stabilize and establish goals for production (e.g. Ontario Ministry of Natural Resources 1982). Montana stocks very few catchable-size trout, and emphasizes wild strain fingerlings in many lake and reservoirs stocking programs (Dick Vincent, Montana Department of Fish, Wildlife, and Parks, personal communication). Colorado maintains its own rainbow trout broodstocks, and seldom uses experimental strains from outside sources (Barry Nehring, Colorado Division of Wildlife, personal communication). They measure hatchery fish production by inch units; total inches of trout are allocated to various management regions based on the percentage of statewide angling effort in the region. Ontario developed guidelines for hatchery fish stocking (Ontario Ministry of Natural Resources 1982). They included criteria to describe the need for stocking, suitability of waters, feasibility, stocking strategies, and assessment programs. They emphasized adequate lead time and **a** prioritization process for hatchery production. They also recommend a standardized assessment program to evaluate stocking success on 10% of their hatchery trout waters annually on a rotating basis.

Evaluating the success of a stocking program is expensive, and may even exceed the cost of stocking. However, an ongoing evaluation program is important to monitor the cost-effectiveness of stocking. Our regional fishery personnel incur no direct costs to stock fish. Consequently, there is little incentive to increase efficiency, and no way to assess costs and benefits of individual programs. Providing fishery managers with the costs of individual stocking programs would help them prioritize hatchery fish allocation. The most straightforward approach is to measure cost per fish in the creel or perhaps costs per angler hour generated. Stocking programs with high cost:benefit ratios could be reduced or dropped altogether. Such changes will likely meet with strong local resistance, but could be made more palatable with good quality data and an educational effort that shows costs and the benefits of reallocating fish to other waters.

Another approach would be to assess total production capabilities (weight or inches) and allocate production to each region based on the proportion of statewide angling effort in that region. Regional Fisheries Managers could prioritize their allocated weight by number and size, preferably in conjunction with the five-year management plan for individual waters. Again, this would provide incentive to evaluate hatchery trout fisheries and maximize efficiency of stocking programs. If increased efficiency leads to long-term reductions in hatchery costs, the savings could be redistributed to the regions for other management activities or equipment.

CONCLUSIONS

The production capabilities of our hatchery system are not well defined. Capabilities vary with the species and sizes grown. The wide variety of species, strains, and sizes we currently produce makes it difficult to determine total production potential. Regardless, estimates of production tradeoffs for various sizes of rainbow trout should be calculated for individual hatcheries. Average annual production (weight) for each facility could represent a "typical" year, with production proportioned into various size classes and some standardized assumptions of egg source and timing. Some variation (approximately ±20%) would be expected from year-to-year.

We suggest exploring this approach in the next year. We are developing information on the relative performance of different sizes of stocked trout, and will ultimately propose stocking guidelines (size and stocking density). Estimates of production capabilities and size tradeoffs will be important to prioritize production to meet these guidelines.

The current process for requesting and stocking hatchery fish is not precise; actual stocking rarely meets original requests. External hatchery limitations, especially our dependence on unreliable egg sources, leads to variable production of different species and strains from year-to-year. This makes it difficult to maintain consistent stocking programs. Continued broodstock development, along with a long-term planning process for hatcheries could help stabilize production. Input on broodstock development and production priorities should come from the fishery managers. Hatchery planning could coincide with the IDFG Five-Year Fisheries Management Plan, and should include alternatives for dealing with disease losses, drought, etc.

Costs of individual stocking programs are needed by regional fishery managers so that they can properly assess cost-effectiveness. Because regional management programs incur no direct, costs for hatchery fish, incentives to increase stocking efficiency are absent. An administrative method to provide these incentives may help increase efficiency.

Evaluation programs, while expensive, are very important to assess the costs and benefits of fish stocking, and to judge the effectiveness of different stocking strategies. Such programs should be a routine part of hatchery trout fishery management, with a given percentage or number of waters in each region to be assessed annually. A standardized approach would also be useful to refine stocking guidelines and strategies in Idaho. Again, however, this type of assessment program will have little value unless hatchery production becomes more consistent.

RECOMMENDATIONS

1. Individual hatcheries should estimate production tradeoffs for spring and fall fingerlings and catchables. State hatchery managers should develop a list of standardized assumptions to facilitate making the estimates.

2. Develop a long-term (five year) planning and request process for hatcheries which corresponds to the IDFG Five-Year Fisheries Management Plan. Both hatchery and management personnel should meet to establish production priorities and capabilities. Discuss and plan alternatives for dealing with unusual circumstances such as drought, etc.

3. Decrease dependence on out-of-state egg sources to stabilize production.

4. Provide costs of individual stocking programs to fishery managers. Encourage assessments of cost per fish caught or harvested or other benefits (e.g cost per angler hour generated). Prioritize stocking programs based on cost effectiveness or social benefits.

5. Establish a standardized statewide evaluation program for hatchery trout fisheries. Designate a number or percentage of fisheries in each region to be evaluated yearly on a rotating basis. Include estimates of total effort and harvest, returns and fish growth. Both hatchery and management personnel should be involved whenever possible.

APPENDICES

Appendix A. Summary of rainbow trout production at Idaho Department of Fish and Game resident fish hatcheries 1982-1991.

Appendix A. Summary of rainbow trout production at Idaho Department of Fish and Game resident fish hatcheries 1982-1991.

Hatchery	Ponds and numbers () produced									
	1982	1983	1984	1985	1986	1987	1988	1989	1990°	1991
American Falls	170,109 (679,200)	0	32,970 (666,843)	90,408 (478,662)	72,329 (222,512)	87,781 (422,314)	160,206 (547,297)	153,525 (904,224)	148,885 (886,000)	202,774 (1,027,762)
Ashton	43,794 (696,439)	16,996 (443,338)	0	59,329 (860,691)	46,851 (588,658)	46,590 (787,319)	17,479 (370,078)	17,213 (322,653)	32,844 (481,963)	22,695 (406,949)
Clark Fork	18,150 (47,890)	14,437 (47,535)	16,267 (68,22)	32,789 (114,366)	35,370 (127,631)	38,822 (122,096)	0	0	0	0
Eagle	40,500 (114,810)	135 (1,140)	0	0	675 (12,285)	385 (1,000)	0	0	0	0
Grace	84,015 (554,344)	53,719 (313,605)	51,045 (188,070)	82,951 (370,437)	74,656 (308,310)	115,250 (437,199)	103,181 (520,091)	100,064 (363,293)	136,388 (1,387,089)	150,123 (1,003,332)
Hagerman	228,370 (1,327,510)	379,192 (2,471,706)	488,358 (2,853,771)	395,847 (2,923,148)	431,412 (2,408,961)	463,658 (2,889,526)	440,284 (2,627,701)	366,481 (2,533,241)	426,981 (4,989,723)	348,190 (3,741,443)
Hayspur	70,860 (1,980,966)	67,915 (1,445,189)	65,287 (1,177,012)	81,101 (904,286)	91,417 (1,044,723)	100,543 (982,515)	83,453 (1,139,195)	95,450 (1,560,101)	106,174 (326,075)	93,320 (496,899)
Kamiah	20,750 (59,815)	15,275 (54,897)	17,000 (43,986)	17,397 (58,977)	16,657 (155,313)	12,696 (133,254)	0	0	0	0
Mackay	106,919 (444,064)	19,748 (86,986)	33,681 (349,333)	59,573 (799,450)	42,689 (538,348)	62,122 (340,117)	97,274 (510,081)	71,654 (331,900)	93,568 (477,509)	72,284 (429,384)
McCall	22,813 (125,855)	33,772 (143,675)	38,563 (180,607)	36,980 (249,500)	39,629 (168,060)	42,335 (176,831)	0	0	0	0
Mullan	23,450 (83,070)	13,540 (54,094)	19,655 (95,533)	16,215 (155,875)	16,507 (63,114)	23,382 (66,684)	0	0	0	0
Nampa	143,589 (462,675)	114,294 (468,478)	193,743 (945,951)	267,635 (1,421,820)	227,881 (1,306,443)	223,272 (1,250,193)	237,280 (1,032,961)	215,425 (1,290,538)	253,514 (3,488,719)	202,485 (2,018,771)

Appendix A. continued

Hatchery	Ponds and numbers () produced									
	1982	1983	1984	1985	1986	1987	1988	1989	1990[a]	1991
Sandpoint	21 (48,404)	1,496 (148,705)	1,780 (151,420)	808 (32,111)	0	0	0	0	0	0
U.S. Hagerman	48,156 (610,226)	29,326 (547,035)	250 (650)	17,820 (106,301)	14,390 (156,773)	19,610 (357,565)	0	0	0	0
U.S. Dworshak/ Kooskia	35,256 (154,956)	48,846 (546,048)	36,099 (96,782)	8,226 (419,136)	0	0	0	0	0	0
Total pounds	1,056,752	808,691	994,653	1,167,079	1,100,363	1,236,448	1,139,836	1,021,344	1,201,724	1,092,516
Total numbers	7,390,324	6,772,431	6,218,180	8,794,760	7,101,131	7,966,618	7,091,008	7,391,473	12,278,130	9,204,093

[a] Change in production record dates; reflects production from October 1989 - December 1990.

Appendix B. Rainbow trout production and costs at IDFG resident hatcheries.

Appendix B-1. Rainbow trout production and costs at IDFG resident hatcheries October 1987 through September 1988.

Hatchery	Put-and-take			Put-and-crow		
	Numbers	Pounds	Cost ($)	Numbers	Pounds	Cost ($)
Cabinet Gorge	0	0	0	0	0	0
Clark Fork	0	0	0	255,138	638	7,501
McCall	0	0	0	88,476	221	8,845
Nampa	937,261	231,780	60,370	95,700	5,500	1,723
Hagerman	1,167,951	412,426	71,883	1,459,750	27,858	89,843
Hayspur	232,406	64,562	90,000	906,779	18,891	40,000
American Falls	464,767	158,631	168,636	82,530	1,575	9,163
Grace	291,145	100,207	53,138	228,946	2,974	4,254
Mackay	235,681	90,895•	59,894	274,400	6,379	20,066
Ashton	49,168	13,241	30,237	320,910	4,058	21,376
	3,378,379	1,071,742	534,158	3,712,629	68,094	202,771

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Appendix B-2. Rainbow trout production and costs at IDFG resident hatcheries October 1988 through September 1989.

Hatchery	Put-and-take			Put-and-aroo:		
	Numbers	Pounds	Cost ($)	Numbers	Pounds	Cost ($)
Cabinet Gorge	0	0	0	22,172	1,478	1,422
Clark Fork	0	0	0	13,351	234	400
McCall	0	0	0	fry only	-	-
Nampa	764,523	190,400	131,042	526,015	24,845	72,652
Hagerman	1,032,575	295,021	68,820	1,500,666	71,460	100,016
Hayspur	261,242	69,473	33,343	1,298,859	25,977	5,667
American Falls	397,310	150,310	95,860	506,914	3,215	5,000
Grace	271,149	91,549	52,500	92,144	8,515	6,000
Mackay	130,900	60,429	58,691	251,000	11,225	6,503
Ashton	51,292	12,825	34,681	271,361	4,388	20,746
	2,908,991	870,007	474,937	4,482,482	151,337	218,406

Appendix B-3. Rainbow trout production and costs at IDFG resident hatcheries October 1989 through September 1990.

Hatchery	Put-and-			Put-and-grow		
	Numbers	Pounds	Cost ($)	Numbers	Pounds	Cost ($)
Cabinet Gorge	0	0	0	22,600	2,499	5,805
Clark Fork	0	0	0	200,165	821	10,000
McCall	0	0	0	48,289	50	1,683
Nampa	378,743	109,625	119,483	3,079,976	143,889	99,129
Hagerman	871,023	238,750	186,062	4,118,700	188,231	282,347
Hayspur	270,853	104,692	157,698	55,222	1,482	10,384
American Falls	483,000	140,735	106,000	403,000	8,150	14,000
Grace	433,885	98,379	107,380	953,204	38,009	47,500
Mackay	294,062	91,268•	65,854	183,447	2,300	18,159
Ashton	111,385	28,812	86,691	370,579	4,032	12,136
	2,842,951	812,261	829,168	9,435,179	389,463	501,143

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Appendix B-4. Rainbow trout production and costs at IDFG resident hatcheries January 1991 through December 1991.

Hatchery	Put-and-take			Put-and-crow		
	Numbers	Pounds	Cost ($)	Numbers	Pounds	Cost ($)
Cabinet Gorge	0	0	0	5,500	156	2,084
Clark Fork	0	0	0	7,589	232	2,000
McCall	0	0	0	66,500	257	9,504
Nampa	350,741	125,324	126,901	1,668,030	77,161	108,517
Hagerman	866,255	211,264	116,048	2,875,188	136,926	225,401
Hayspur	246,839	83,328	141,658	250,060	9,992	16,986
American Falls	779,000	180,971	156,850	248,762	21,803	18,750
Grace	394,362	119,528	102,600	608,970	30,595	54,591
Mackay	209,419	56,506'	99,385	219,965	15,778	29,089
Ashton	49,054	20,089	44,544	357,859	2,606	23.079
	2,895,670	797,010	787,986	6,308,423	295,506	490,000

J3_APB4

Appendix C. Comparison of actual plants to original requests for put-and-take fish.

Appendix C-1. Comparison of actual plants to original requests for put-and-take fish, 1990. "Y" denotes request was met and "N" denotes request was not met. See text for explanation of comparison categories.

Water	Number	Size	Species	Date	Species/ numbers	Extra species	Extra numbers	Total request
Brush	Y	Y	Y	Y	Y	N	Y	Y
Smith	Y	Y	Y	Y	Y	N	Y	Y
Robinson	Y	Y	Y	Y	Y	N	N	Y
Kelso	Y	Y	Y	Y	Y	N	N	Y
Cocollala	Y	Y	Y	N	Y	Y	Y	N
Spirit	N	Y	Y	N	N	N	N	N
Hauser	N	Y	Y	N	N	N	N	N
Lower Twin	N	Y	Y	N	N	N	N	N
Fernan	Y	Y	Y	N	Y	Y	Y	N
Coeur d"Alene River	N	Y	Y	Y	N	N	N	N
St. Joe River	N	Y	Y	Y	N	Y	N	N
Manns Lake	Y	N	Y	N	Y	Y	Y	N
Soldiers Meadow	N	N	Y	N	N	Y	N	N
Winchester	Y	N	Y	N	N	Y	Y	N
Spring Valley	Y	N	N	N	N	Y	Y	N
Moose Creek Reservoir	N	N	Y	N	N	Y	N	N
Elk Creek Reservoir	Y	N	Y	Y	N	Y	N	N
Cascade Reservoir	N	N	N	Y	N	N	N	N
Brownlee Reservoir	Y	Y	Y	N	Y	N	Y	N
C.J. Strike	Y	Y	Y	N	Y	Y	Y	N
Brundage	N	N	N	N	N	N	N	N
Goose Lake	Y	Y	Y	N	Y	N	N	N
Warm Lake	N	Y	Y	Y	N	N	N	N
Mann Creek Reservoir	Y	Y	Y	N	N	Y	N	N
Sagehen Reservoir	N	N	Y	N	N	N	N	N
Horsethief Reservoir	N	Y	Y	N	N	N	N	N
Little Payette Lake	Y	Y	Y	Y	Y	N	N	Y
Payette Lake	Y	Y	Y	Y	Y	N	Y	Y
Upper Payette Lake	Y	Y	Y	Y	Y	N	N	Y
N. Fork Payette River	Y	Y	Y	Y	Y	N	N	Y
Lake Lowell	Y	N	Y	Y	Y	N	Y	N
Indian Creek Reservoir	Y	Y	Y	N	Y	N	Y	N
Lucky Peak Reservoir	N	Y	Y	N	N	Y	N	N
Arrowrock Reservoir	Y	Y	Y	N	Y	N	Y	N
Boise River	N	N	Y	N	N	Y	N	N
Wilson Reservoir	N	N	Y	Y	N	N	N	N
S. Fork Boise River	Y	Y	Y	N	Y	N	Y	N
Salmon Falls Creek Res.	N	N	Y	N	N	N	N	N
Lake Walcott	Y	Y	Y	N	Y	N	Y	N
Emerald	Y	Y	Y	N	Y	N	Y	N
Oakley	N	Y	Y	N	N	N	N	N
Bell Rapids	Y	Y	Y	N	Y	N	Y	N
Banberry	Y	Y	Y	Y	Y	Y	Y	Y
Riley Creek	Y	Y	Y	N	Y	N	Y	N
Anderson Ranch Reservoir	Y	Y	Y	Y	Y	N	N	Y
S. Fork Boise River	Y	Y	Y	N	Y	N	Y	N
Little Wood Reservoir	Y	Y	Y	N	Y	N	N	N

J3_APC1

Appendix C-1. continued.

Water	Number	Size	Species	Date	Species/ numbers	Extra species	Extra numbers	Total request met
Magic Reservoir	Y	Y	Y	Y	Y	N	Y	Y
Warm Springs Creek	Y	Y	Y	Y	Y	N	N	Y
American Falls Reservoir	Y	Y	Y	Y	Y	N	Y	Y
Daniels	Y	Y	Y	N	Y	N	N	N
Deep Creek Reservoir	Y	Y	Y	N	Y	N	Y	N
Devils Creek Reservoir	Y	Y	Y	N	Y	N	Y	N
Lamont	Y	Y	Y	Y	Y	N	N	Y
Twin Lakes	N	Y	Y	N	N	N	N	N
Treasureton	N	Y	Y	N	N	N	N	N
Winder Reservoir	Y	Y	Y	Y	Y	N	Y	Y
Bear River	Y	N	Y	N	Y	N	Y	N
Ririe Reservoir	Y	Y	Y	N	N	N	N	N
Gem Lake	N	Y	Y	Y	N	N	N	N
Snake River-Idaho Falls	Y	N	Y	Y	N	Y	Y	N
Willow Creek	N	Y	Y	N	N	Y	N	N
Sand Creek #2	N	Y	Y	N	N	N	N	N
Island Park Reservoir	Y	Y	Y	N	Y	N	Y	N
Henrys Fork	N	N	Y	Y	N	N	N	N
Mackay Reservoir	Y	N	Y	N	Y	N	Y	N
Birch Creek	N	N	Y	Y	N	N	N	N
Stanley Lake	N	N	Y	Y	N	N	N	N
Redfish Lake	Y	Y	Y	Y	Y	N	Y	Y
Proportion met	5/76	54/76	73/76	30/76	44/76	17/76	35/76	17/76
Percentage met	66%	71%	96%	39%	58%	22%	46%	22%

J3_APC1

Appendix C-2. Comparison of actual plants to original requests for put-and-take fish, 1991. "Y" denotes request was met and "N" denotes request was not met. See text for explanation of comparison categories.

Water	Number	Size	Species	Date	Species/ numbers	Extra species	Extra numbers	Total request met
Brush	Y	Y	Y	N	Y	N	Y	N
Smith	N	Y	Y	N	N	Y	N	N
Priest	N	Y	Y	N	N	N	N	N
Cocoltala	Y	Y	Y	Y	Y	N	Y	Y
Pend Oreille	N	N	N	N	N	N	Y	N
Spirit	N	N	N	N	N	N	Y	N
Hauser	Y	N	N	Y	N	Y	N	N
Lower Twin Lake	Y	N	Y	N	Y	Y	Y	N
Hayden Lake	Y	N	N	N	N	Y	Y	N
Clearwater River	Y	N	Y	Y	Y	Y	Y	N
Manns Lake	N	Y	N	Y	N	Y	N	N
Waha	Y	N	Y	Y	Y	N	Y	N
Soldiers Meadow	N	N	N	Y	N	Y	N	N
Winchester Reservoir	Y	Y	N	Y	N	N	Y	N
Spring Valley	Y	N	N	Y	N	Y	Y	N
Moose Creek Reservoir	Y	Y	N	Y	N	N	N	N
Elk Creek Reservoir	Y	Y	N	N	N	Y	N	N
Lower Salmon River	Y	Y	Y	N	Y	Y	N	N
Cascade Reservoir	N	N	N	N	N	Y	Y	N
Hells Canyon Reservoir	N	Y	N	Y	N	Y	N	N
Brownlee Reservoir	Y	N	Y	N	N	Y	Y	N
C.J. Strike Reservoir	Y	N	N	N	N	Y	N	N
Brundage	Y	Y	Y	N	Y	N	Y	N
Goose Lake	Y	Y	Y	N	Y	N	Y	N
Warm Lake	N	N	N	N	N	N	N	N
Deadwood Reservoir	N	N	Y	N	N	N	Y	N
Little Payette Lake	N	N	Y	Y	N	N	N	N
Payette Lake	N	N	N	N	N	Y	Y	N
Lake Lowell	Y	Y	Y	N	Y	N	Y	N
Indian Creek Reservoir	N	N	Y	N	N	Y	N	N
Lucky Peak Reservoir	Y	Y	N	N	N	Y	N	N
Arrowrock Reservoir	Y	N	Y	N	N	Y	N	N
Wilson Drain	Y	N	Y	N	Y	N	N	N
Salmon Falls Creek Reservoir	Y	Y	Y	N	Y	N	Y	N
Lake Walcott	Y	Y	Y	Y	N	Y	Y	N
Sublett	N	Y	N	Y	N	N	Y	N
Anderson Ranch Reservoir	N	N	N	N	N	N	Y	N
Little Wood Reservoir	Y	Y	Y	Y	Y	N	Y	Y
Magic Reservoir	N	Y	Y	N	N	N	N	N
American Falls	N	N	Y	Y	N	N	N	N
Hawkins	N	N	N	N	N	Y	N	N
Chesterfield Reservoir	N	N	N	N	N	N	Y	N
Blackfoot Reservoir	N	N	N	N	N	N	N	N
Springfield	Y	N	Y	Y	Y	N	Y	N
Bear River	N	N	Y	Y	N	N	N	N
Daniels	N	N	N	N	N	Y	Y	N
Devils Creek Reservoir	Y	N	Y	N	N	Y	N	N
Lamont	Y	N	Y	N	N	N	N	N

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Appendix C-2. continuted.

Water	Number	Size	Species	Date	Species/ numbers	Extra species	Extra numbers	Total Request met
Twin Lakes	N	N	N	N	N	N	N	N
Oxbow Reservoir	N	Y	N	N	N	Y	N	N
Treasureton	Y	N	Y	N	Y	N	Y	N
Winder Reservoir	Y	N	N	N	N	Y	N	N
Ririe Reservoir	N	N	Y	N	N	N	Y	N
Willow Creek	N	N	N	N	N	N	N	N
Sand Creek #2	Y	Y	Y	Y	Y	N	Y	Y
Island Park Reservoir	Y	N	Y	N	N	N	Y	N
Henrys Lake	Y	N	Y	Y	Y	N	Y	N
Henrys Fork	Y	N	Y	N	Y	N	Y	N
Mackay Reservoir	Y	N	Y	N	Y	N	Y	N
Mud Lake	Y	N	Y	Y	Y	Y	Y	N
Stanley Lake	Y	N	Y	N	Y	N	Y	N
Proportion met	36/62	21/62	36/62	20/62	21/62	27/62	35/62	3/62
Percentage met	58%	34%	58%	32%	34%	44%	56%	5%

J3_APC2

JOB PERFORMANCE REPORT

State of: Idaho

Name: Put-and-grow Trout Evaluations

Project No.: F-73-R-15

Title: Rainbow Trout Strain Synopsis

Subproject No.: V

Study No.: III

Job: 4

Period Covered: April 1, 1992 to March 31, 1993

ABSTRACT

The Idaho Department of Fish and Game commonly raises up to 13 strains of rainbow trout *Oncorhynchus mykiss* for stocking statewide. In most fisheries the benefits of strain selection are unclear. We reviewed available literature on hatchery and field performance of various rainbow trout strains. We used the information to describe the expected benefits of strain selection for individual Fisheries and for statewide use.

Past strain evaluation experiments show that fishery performance (survival, growth, returns) can vary markedly among rainbow trout strains. However, most evaluations we reviewed included few spacial or temporal replications, and no strains have been evaluated over a broad geographical area. Variability in broodstock quality, size of fish stocked, time and date of stocking and the fishery environment can also influence the performance of a particular strain. With these constraints on available information, selecting the best strain or strains for specific fisheries or statewide use is difficult.

Strain selection is more important for put-and-grow fisheries (where long-term survival and growth is required) than for put-and-take programs. Domesticated strains typically do not survive well under natural conditions, whereas, wild strains generally show superior survival and growth, and may be longer-lived than domesticated fish. Late-maturing stocks may have particular application in waters managed for trophy trout.

For put-and-take programs we should expand our own broodstock production, and find reliable commercial egg sources (regardless of strain) to supplement in-state production. For put-and-grow fish we should consider developing a wild lacustrine broodstock, or infusing wild genes into our current Kamloop rainbow trout broodstock. Experimental strains should be stocked with same-size fish from our own broodstocks for comparison.

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INTRODUCTION

The Idaho Department of Fish and Game (IDFG) resident hatchery system produces a wide variety of rainbow trout *Oncorhynchus mykiss* strains for stocking in streams, lakes, and reservoirs statewide. The use of multiple rainbow trout strains stems from two sources: 1) hatcheries receiving eggs from other agencies or private suppliers to supplement our own broodstock production, and 2) requests for specific rainbow trout strains from regional fishery managers.

Resident fish production goals are determined by management requests. Many of these requests are for species or strains for which we have no in-state egg sources. In 1992, our hatchery egg source included 13 rainbow trout strains and three rainbow trout X cutthroat trout O. *clarki* hybrid strains (Mike Larkin, IDFG Resident Hatchery Manager, personal communication).

We use individual strains to meet specific fishery management objectives, with the expectation that certain strains outperform others. Strain characteristics, including disease and environmental tolerance, growth potential, survival, vulnerability to anglers, feeding habits, and migrational tendencies are considered by Idaho biologists when selecting strains for stocking.

Reliance on inconsistent commercial egg sources often makes it difficult to meet specific requests. We generally do not consider hatchery performance or cost to rear fish when selecting strains. Variable hatchery performance among strains (Hansen and Stauffer 1971; Dwyer and Piper 1984; Hudy 1983; Partridge 1985) and the need to keep them in separate raceways taxes the hatchery system. Because commercial egg sources are unreliable and of variable quality, production of different strains varies from year-to-year regardless of requests.

Despite the use of alternate strains to improve hatchery trout fisheries in Idaho, we have not quantified the benefits derived from strain manipulation. Other than on some individual water bodies (Maiolie 1987), it remains unclear whether strain selection can consistently increase return to creel, survival, catch rates, or growth of hatchery rainbow trout. Do the fishery benefits obtained from strain manipulation compensate for the increased hatchery costs?

Although fish strain evaluations have been conducted nationwide for many years, there is little information on post-stocking performance for most strains. Evaluations have generally been limited to comparative performance of select strains in relatively few waters, and with few or no replications over time (e.g. Rawstron 1972; Dolan and Piper 1979; Hudy 1980; Heimer 1984; Partridge 1985). In strain comparisons that did include replications over time or among waters, performance differences were often inconsistent or contradictory (e.g Rawstron 1972; Hudy 1980 versus Hudy and Berry 1983; Berry et al. 1982 versus Babey 1983; Ayles and Baker 1983).

Since 1982, IDFG has conducted several strain evaluations or comparisons. Reininger (1984) and Partridge (1985, 1987, 1988) investigated the performance of various rainbow trout strains in Magic, Mormon, and Anderson Ranch reservoirs from 1982-88. Heimer (1984) compared performance of two strains in American Falls Reservoir. Maiolie (1987) evaluated six strains in Ashton Reservoir. These studies revealed relative performance trends for a few strains, yet in each case the authors recommended further evaluations. Other than the trout strain guidelines developed for Ashton Reservoir (Maiolie 1987), few specific management practices have changed as a result of these studies.

A better understanding of specific strain performances may direct hatchery and fishery management practices more efficiently. If it is possible to select a few strains that consistently outperform others, we could streamline production and cut hatchery costs significantly (e.g. Maiolie 1987; Jackson and Lovgren 1992). For example, Maiolie (1987) suggested that by using put-and-take Hayspur rainbow trout (RB) in preference to Finespot cutthroat trout or generic rainbow trout in Ashton Reservoir, we could reduce stocking densities by 50%. Alternatively, if strain selection does not show consistent benefits, perhaps we can focus on a few select strains (our own broodstocks or others that are reliable) and still meet management goals. Elimination of some currently used strains, or addition of others may make sense from both **a** fishery management and an economical perspective.

OBJECTIVES

The management goal of this project is to maximize the effectiveness of IDFG hatchery trout stocking programs.

1. To present synopsis of strain evaluation literature for rainbow trout.
2. To describe strain characteristics important to performance in fisheries.
3. To provide general guidelines for strain selection.
4. To describe costs and expected benefits of strain manipulation.

METHODS

We reviewed journal articles, published and unpublished papers, and other related materials for information on rainbow trout strain evaluations. We summarized information under the following categories: behavior, vulnerability, growth, return/harvest, survival, reproduction, and cost. Where possible, we tried to emphasize trends or inconsistencies in results among the various authors. We used the information to describe the expected benefits from strain selection.

A list of authors we reviewed and the rainbow trout strains they evaluated is presented in Table 1.

RESULTS AND DISCUSSION

Behavior, Vulnerability, and Catchability

Behavioral differences among rainbow trout strains can influence their vulnerability to anglers. Important behavioral traits that affect survival to

Table 1. List of authors cited in the text, and rainbow trout strains evaluated

Authors)	Strains
Ayles (1975)	Pennask, Tunkwa, Idaho domestic
Ayles and Baker (1975)	Idaho, Pennask, Tunkwa, Nisqually, Sunndalsora, Manx, Mt. Lassen
Babey (1983)	Tensleep, Sand Creek, Shepherd-of-the-Hills
Boles et al. (1964)	Kamloops, Mt. Shasta, Domestic Hot Creek
Brauhn and Kincaid (1982)	Wytheville, Fish lake, Fall growth, Fall standard
Close and Hassinger (1981)	Kamloops, Madison, Donaldson
Cordone and Nicola (1970)	Kamloops, Shasta, Whitney, Virginia
Dolan and Piper (1984)	Domestic Winthrop, Spring standard growth, McConaughy, Fish Lake
Dwyer et al. (1980)	Winthrop, Spring standard growth, McConaughy, Fish Lake
Dwyer and Piper (1984)	Domestic Winthrop, Spring standard growth, McConaughy, Fish Lake
Fay and Pardue (1986)	Standard winter, Ennis, Sand Creek, Fish lake, McConaughy
Hansen and Stauffer (1971)	Domestic rainbow, West coast rainbow, Michigan wild rainbow
Heimer (1984)	American Falls, Batise
Hensler (1987)	DeSmet, Arlee, Eagle Lake, McBride cutthroat
Hudy (1980)	Tensleep, Sand Creek, Beity, Shepherd-of-the-Hills, New Zealand, Fish Lake x DeSmet, DeSmet
Hudy and Berry (1983)	Sand Creek, Tensleep, Shepherd-of-the-Hills
Jackson and Lovgren (1992)	Spokane, Goldendale, South Tacoma
Klein (1983)	Lake Desmet, Domestic strain
Kmiecik (1980)	Nevin, Desmet x McConaughy, Manchester x Wytheville, Erwin
Maiolie (1987) Hayspur,	Mt. Lassen, Bear Lake cutthroat, Finespot cutthroat, Henry's Lake cutthroat, "generic" rainbow, Mt. Shasta, Sand Creek, Kamloops
Partridge (1985)	Mt. Lassen, Kamloops, Mt. Shasta, Hayspur
Partridge (1987)	McConaughy, Mt. Shasta, Mt. Lassen
Partridge (1988)	McConaughy, Mt. Shasta, Mt. Lassen
Rawstron (1972)	Coleman kamloops, Mt. Whitney
Rawstron (1973)	Coleman kamloops, Shasta, Whitney
Rawstron (1977)	Coleman kamloops, Shasta, Whitney
Reininger (1984)	Mt. Lassen, Mt. Whitney, Kamloops, Mt. Shasta, Hayspur
Schneidervin and Brayton (1992)	Gerrard Kamloops, Eagle Lake, McConaughy

the creel include migratory tendencies, dispersion rates, habitat preference and foraging preferences.

Several authors reported that migrational tendencies differ among strains (Hansen and Stauffer 1971; Rawstron 1973; Hudy 1980; Boles et al. 1983), while others found no migrational differences (Fay and Pardue 1986; Hudy and Berry 1983; Heimer 1984). Consistent trends in migratory behavior are apparent only in a few strains. In several studies, Mt. Whitney RB strain had higher emigration rates from reservoirs than other strains (Rawstron 1973; Reininger 1984; Partridge 1985, 1988). The wild DeSmet strain rainbow trout migrated at higher rates than domestic strains (Klein 1983). Cordone and Nicola (1970) suggested Kamloop RB emigrated from a reservoir at higher rates than the Mt. Whitney RB, Mt. Shasta RB, and Virginia RB strains. Boles et al. (1964) also found Kamloop RB to emigrate at substantially higher rates than the Mt. Shasta RB and Hot Creek RB strains. Reininger (1984) and Partridge (1985) speculated that the Mt. Lassen RB strain left impoundments at high rates. Hudy (1980) found that the Beity RB strain emigrated to inlet streams at a higher rate than other strains in a Utah reservoir.

Post-stocking migration may alter or bias survival estimates used to assess stocking success, and may decrease the cost effectiveness of specific stocking programs (Moring 1982). Brauhn and Kincaid (1982) believed low survival of two rainbow trout strains (Fall growth and Fall standard) was due to emigration from the pond by drifting or swimming over the dam. Maiolie (1987) inferred that any trout in an "open system" that strays from the point of stocking will not benefit the fishery. In Lake Michigan, Hansen and Stauffer (1971) found that two wild strains of rainbow trout strayed farther from the planting location than did a domestic strain.

For most rainbow trout strains little or no information on migratory tendencies is available. In general, wild strains tend to emigrate at higher rates than domesticated strains, but emigration appears to vary even among domestic strains. In open systems, especially streams, emigration can reduce effective stocking densities and decrease returns.

Strain differences in spatial distribution within a fishery can affect vulnerability of the fish to boat or bank anglers (Kincaid and Berry 1983). Again, however, little or no information on habitat preference or distribution is available for most rainbow trout strains. Kamloop RB, Mt Shasta RB, and Hayspur RB preferred the limnetic zone in Magic Reservoir (Reininger 1984), limiting their availability to bank anglers. Rawstron (1972) found Coleman Kamloop RB moved quickly to the limnetic zone. Cordone and Nicola (1970) noted Kamloop RB occupied open waters in a reservoir, while Mt. Whitney RB, Mt. Shasta RB, and Virginia RB strains seem to distribute equally between littoral and limnetic zones. Kamloop RB were thus less susceptible to harvest by shore anglers. Kamloop RB were also more pelagic and more available to boat anglers than the Eagle Lake RB or McConaughy RB strains in Flaming Gorge Reservoir (Schneidervin and Brayton 1992).

In most evaluations of various Kamloop RB stocks, they used the limnetic zone more so than other strains. No conclusions for other strains are possible with the current information. Distribution and vulnerability are probably a function of habitat preference and availability. Kamloop RB alone are probably a poor choice in larger waters with predominantly shoreline angling. Best returns would be expected in large waters with good boating access or smaller waters where they remain vulnerable to shore anglers.

Fishery biologists often try to select rainbow trout strains with specific foraging behavior to take advantage of natural forage availability. Matching strains to the forage base should optimize feeding and growth. A typical scenario is selection of piscivorous strains to utilize non-game forage fish. In practice, however, this approach appears unreliable. Strains which are piscivorous in one system may be less so in others. In their native system, Eagle Lake RB fed exclusively on young-of-the-year tui chubs Gila bicolor in summer, and fed very little on the abundant invertebrates (McAffee 1966). In several Montana waters, Eagle Lake RB were much less piscivorous even with ample forage fish available (Hensler 1987). Reininger (1984) and Partridge (1985) both found the Mt. Shasta RB strain to be piscivorous. Partridge (1983, 1985) found Mt. Shasta RB to feed on yellow perch Perca flavescens. Hensler (1987) found the DeSmet RB strain to be piscivorous, whereas, Hudy (1980) found the DeSmet RB rainbows to be primarily a planktivore. The Arlee strain may be particularly adept at utilizing Daphnia as forage and may be an efficient strain to plant in waters with low zooplankton densities (Hensler 1987). Maiolie (1987) noted no feeding differences between domestic hatchery trout strains and wild trout in Ashton Reservoir. Food habits of smaller trout (<350 mm) may be similar regardless of strain (Hensler 1987).

Various authors differentiate between vulnerability and catchability, inferring that vulnerability is related to habitat preference and catchability is related to feeding behavior or aggressiveness. For example, two strains, both with a preference for littoral habitats may be equally vulnerable to bank angling. However, the strains could differ in catchability if one is more wary or has different feeding habits. Both vulnerability and catchability can influence return-to-the-creel, and they may differ among strains (Boles et al. 1964; Close and Hassinger 1981; Brauhn and Kincaid 1982; Fay 1983; Reininger 1984; Partridge 1985).

Partridge (1985) found that the Mt. Lassen RB strain was highly vulnerable to bank anglers in Magic Reservoir. In Anderson Ranch Reservoir, Mt. Lassen RB were harvested primarily by boat anglers in littoral areas, again suggesting they did not use the limnetic portions of the reservoir (Partridge 1987). Reininger (1984) reported Mt. Lassen RB were more vulnerable to bank anglers than other strains in Magic Reservoir.

Partridge (1985) reported that Hayspur RB have similar bank and boat vulnerabilities. However, Maiolie (1987) concluded the Hayspur RB was preferred in a study reservoir dominated by shore fisherman because they had a higher harvest rate by bank anglers. Hayspur RB did not disperse far from the point of stocking, rendering them highly vulnerable to bank anglers immediately after planting (Maiolie 1987).

The Mt. Whitney RB strain was more vulnerable to bank fishing than to boat fishing in Magic Reservoir (Reininger 1984). However, Cordone and Nicola (1970) found Mt. Whitney RB vulnerability equal between bank and boat anglers.

Reininger (1984) and Partridge (1985) found the Mt. Shasta RB strain to be more vulnerable to shore anglers than to boat anglers in Magic Reservoir. In contrast, Cordone and Nicola (1970) found the Shasta RB strain showed no difference in bank and boat vulnerability.

In a California reservoir, boat anglers caught Kamloop RB at higher rates than did shore anglers (Cordone and Nicola 1970). Higher survival of Coleman Kamloop RB compared to other strains may be due to rapid movement to the limnetic zone shortly after planting and low vulnerability to bank anglers (Rawstron 1972, 1973). Kamloop RB also dominated the rainbow trout harvest in the limnetic zone of Flaming Gorge Reservoir (Schneidervin and Braytc-' 1992). Contrary to most studies, Partridge (1987) found Kamloop RB did not extensively use the limnetic zone in Magic reservoir and were the only strain observed in bank creels with 39% of their total estimated harvest caught from the bank. In Lake Superior, Donaldson RB and Kamloop RB strains moved offshore shortly after stocking, while Madison RB strain fish remained near the stocking site for several months (Close and Hassinger 1981). Initial (first-year) returns were 3.9, 1.7, and 25.7%, respectively. Coleman Kamloop RB tended to become oriented to the surface sooner in the fall and thus became more vulnerable to anglers (Rawstron 1973). Hudy (1980) found no differences in boat and shore vulnerability among seven rainbow trout strains.

Rainbow trout strains can also differ in their vulnerability to various angling methods. Dwyer et al. (1980) found that McConaughy RB and Fish Lake RB strains were more vulnerable to lure and fly fisherman than were domestic strains. Boles et al. (1964) found Kamloop RB to be more vulnerable to fly fishing than comparable plants of other strains. Hudy and Berry (1983) found no difference in vulnerability to different fishing gear among three domestic strains.

Comparisons of catchability among strains has received less attention than vulnerability. Several authors noted that wild strains in natural habitats exhibit lower catchability than domestic fish (Flick and Webster 1976; Frasier 1981; Ayles and Baker 1983; Klein 1983). Kmiecik (1980) concluded difference in catchability among strains are due to genetic differences. Finding similar results in two separate fisheries, Kmiecik (1980) concluded the hybrid strain (wild X domestic) was more wary than the domesticated Nevin RB strain; as a result the hybrid was less catchable. Braun and Kincaid (1982) suggested faster growing rainbow trout strains are more catchable than slower growing strains.

Growth

Numerous studies have shown growth differences among rainbow trout strains (e.g. Rawstron 1977; Brauhn and Kincaid 1982; Hudy and Berry 1983; Dwyer and Piper 1984), while others reported no significant growth differences (Rawstron 1973; Close and Hassinger 1981; Hudy and Berry 1983; Babey 1983; Reininger 1984; Schneidervin and Brayton 1992). Table 2 summarizes the growth data reviewed by each author.

After one year in Magic Reservoir, growth of the Mt. Lassen RB, Shasta RB, and Hayspur RB was similar and slightly greater than Kamloop RB (Partridge 1985). Partridge (1987) found Mt. Lassen RB to grow slightly slower than Kamloop RB and Hayspur RB but slightly faster than Shasta RB in Anderson Ranch Reservoir. Growth differences were not significant due to small sample sizes. Reininger (1984) discovered no significant difference in growth between Kamloop RB, Mt. Shasta RB, and Hayspur RB strains after 4 months in Magic Reservoir. When comparing reservoir performance of Mt. Shasta RB, Mt. Whitney RB, and Coleman Kamloop RB, Rawstron (1973) found no significant differences in growth among

Table 2. Comparative growth for various rainbow trout strains.

Water	Year	Strains	Time period	Growth		Citation
				Length	Weight	
Canadian Prairie aquaculture lakes	1972-78	Idaho	1 summers growth		+268 g	Ayles and Baker (1983)
		Pennask			+183 g	
		Tunkwa			+213 g	
		Nisqually			+264 g	
		Sunndalsora			+370 g	
		Manx			+143 g	
		Mt. Lassen			+223 g	
		Qu' Appelle				
East Canyon Reservoir. Utah	1981	Tensleep	450 days	321 mm		Babey (1983)
		Sand Creek		319 mm		
		Shepherd-of-the-Hills		325 mm		
	1982	Tensleep	225 days	263 mm		
		Sand Creek		256 mm		
		Shepherd-of-the-Hills		252 mm		
1 Ha Pond	1974	Wytheville	233 days		+653%	
		Fish Lake			+418%	
Lake Superior	1972-78	Kamloops	4 years	620 mm	3.18 ks	Close and Hassinger (1981)
		Donaldson		605 mm	3.45 kg	
		Madison		559 mm	2.27 kg	
Spring Branch Creek, VA	1981	Standard Winter	4 months	4.7 mm/mo	6.6 g/mo	Fry and Pardue (1986)
		Fish Lake		3.5 mm/mo	1.1 g/mo	
		McConaughy		3.4 mm/mo	2.3 g/mo	
		Sand Creek		2.8 mm/mo	2.5 g/mo	
American Falls Reservoir. ID	1981	Batise	1 year	+228 mm	832 g	Heimer (1984)
		American Falls		+195 mm	651 g	
	1982	Batise	1 year	+120 mm	322 g	
		American Falls		+119 mm	325 g	
Porcupine Reservoir, UT	1978-79	Tensleep	11 months	+157 mm	+129 g	Hudy (1980)
		Sand Creek		+155 mm	+128 g	
		Beity		+152 mm	+118 g	
		Shepherd-of-the-Hills		+151 mm	+109 g	
		Fish Lake x Desmet		+145 mm	+103 g	
		New Zealand		+142 mm	+86 g	
Porcupine Reservoir, UT	1979-80	Sand Creek	1 year	+194 mm	+218 g	Hudy and Berry (1983)
		Tensleep		+189 mm	+208 g	
		Shepherd-of-the-Hills		+182 mm	+199 g	

Table 2. Continued.

Water	Year	Strains	Time period	Growth[a] Length	Growth[a] Weight	Citation
Magic Reservoir, ID	1982-84	Mt. Lassen	1 year	0.64 mm/day	0.86 g/day	Partridge (1985)
		Shasta		0.64 mm/day	0.89 g/day	
		Hayspur		0.63 mm/day	0.95 g/day	
		Kamloops		0.60 mm/day	0.78 g/day	
Magic Reservoir, ID	1985	Mt. Lassen	16 months	0.47 mm/day	0.82 g/day	Partridge (1987)
		Shasta		0.47 mm/day	0.57 g/day	
		Hayspur		0.49 mm/day	0.73 g/day	
		Kamloops		0.51 mm/day	0.75 g/day	
Lake Berryessa, LA	1969	Shasta	5 months		450 g	Rawstron (1973)
		Coleman Kamloops			431 g	
		Whitney			440 g	
	1970	Shasta	5 months		486 g	Rawstron (1973)
		Coleman Kamloops			486 g	
		Whitney			486 g	
Marta Collins Reservoir, CA	1970	Shasta	17 months	no difference among strains		Rawstron (1973)
		Coleman Kamloops				
		Whitney				
Magic Reservoir, ID	1983	Kamloops	4 months	1.2 mm/day	0.9 g/day	Reininger (1984)
		Mt. Shasta		1.2 mm/day	0.9 g/day	
		Hayspur		1.2 mm/day	0.9 g/day	
Four Washington Lowland Lakes	1990-91	South Tacoma	4 months	0-126 mm		Jackson and Lovgren (1992)
		Spokane		0-83 mm		
		Goldendale		0-46 mm		
Flaming Gorge Reservoir, UT-WY		Kamloops	2 years	0.30 mm/day		Schneidervin and Brayton (1992)
		Eagle Lake		0.25 mm/day		
		McConaughy		0.25 mm/day		

[a] Growth expressed as mean length or weight at end of the period or length or weight gain per unit time.

strains in multiple test waters. Four years after release in Lake Superior, Kamloop RB and Donaldson RB strains were similar in size but larger than Madison RB strain fish (Close and Hassinger 1981). Braun and Kincaid (1982) noted a greater weight gain for the Wytheville RB strain than the Fish Lake RB strain in a 233-d period. In American Falls Reservoir, Heimer (1984) showed 1981 planted Batise RB grew faster than American Falls RB. In 1982, both strains grew considerably slower but ranked the same. Hudy (1980) found the Tensleep RB to grow faster than the Sand Creek RB, Beity RB, Shepherd-of-the-Hills RB, Fish Lake RB x DeSmet RB, and New Zealand RB strains after almost a full year in Porcupine Reservoir, Utah. However, in the same reservoir, Hudy and Berry (1983) found growth of the Sand Creek RB strain to be greater than Tensleep RB or Shepherd-of-the-Hills RB strains after 14 months. They concluded the growth differences were not enough to be of management importance. In another Utah reservoir, the Tensleep RB strain grew slightly better than the Sand Creek RB or Shepherd-of-the-Hills RB strains (Babey 1983). Ayles and Baker (1983) found Idaho fish (from Soda Springs Fish Hatchery) grew significantly faster than the Pennask RB, Tunkwa RB, and Manx RB strains and slower than the Niqually RB, Sunndalsona RB,and Mt. Lassen RB strains.

Growth differences among strains may be relatively small compared to growth differences within strains among lakes (Ayles and Baker 1983). Domestic rainbow trout strains typically out-perform wild strains under hatchery conditions, but show inferior growth rates under natural conditions (Cordone and Nicola 1970; Hansen and Stauffer 1971; Dwyer and Piper 1984; Partridge 1988). However, in some instances, wild strains showed poorer post-stocking growth than domestic strains (Klein 1983; Fay and Pardue 1986).

Food conversions and growth rates in the hatchery were lower for wild strains than for domestic strains (Dwyer and Piper 1984; Partridge 1988). Partridge (1988) suggests the major reason for slower hatchery growth in McConaughy RB and Eagle Lake RB is due to their avoidance behavior while in the raceways. Mt. Shasta RB strain showed significantly better hatchery growth than Kamloop RB and Hayspur RB strains (Partridge 1988). Hatchery performance of Shepherd-of-the-Hills RB strain was superior to the Tensleep RB and Sand Creek RB strains, but post stocking performance was inferior to the others (Hudy and Berry 1983).

Catch Rates and Returns

Harvest and return rates are a function of angling effort and the vulnerability and catchability of the fish. Differences in returns and harvest rates among rainbow trout strains has been documented (Close and Hassinger 1981; Hudy and Berry 1982; Babey 1983; Dwyer and Piper 1984; Partridge 1985; Fay and Pardue 1986; Maiolie 1987). However, duplication of experiments has often failed to produce similar results (Rawstron 1972; Berry et al. 1982; Dwyer and Piper 1984).

Kamloop RB fingerling return-to-creel was lowest providing a catch rate of 0.001 fish/hr to both bank and boat anglers on Magic Reservoir (Reininger 1984). Also on Magic Reservoir, Partridge (1985) found Mt. Shasta RB (0.014 fish/h) and Hayspur RB (0.012 fish/h) provided higher harvest rates than Kamloop RB (0.004 fish/h) and Mt.Lassen RB (<0.001 fish/h) despite similar stocking rates.

Seven groups of catchable-size Kamloop RB released in four different years were harvested at rates ranging from 17-33% (Cordone and Nicola 1970). Close and Hassinger (1981) reported recoveries during the summer season (3 months) of fall fingerling rainbow trout were 0.1% for Kamloop RB and 2.4% for Donaldson RB strains, whereas recoveries of put-and-take rainbow trout were 3.9% for Kamloop RB, 1.7% for Donaldson RB and 25.7% for Madison RB strain. Kamloop RB had the best overall return by numbers (7.9%) and fall-stocked Donaldson RB strain had the best recovery by weight (2.4 kg/kg stocked). Boles et al. (1964) reported a 43% return for a put-and-take (8.0/lb) Kamloop RB plant, but noted that larger domestic Hot Creek RB (74-90% return) were better suited for put-and-take stocking. In a 4-year study, Kamloop RB provided a consistently higher return by number and weight than Eagle Lake RB or McConaughy RB strains in Flaming Gorge Reservoir (Schneidervin and Brayton 1992). Rawstron (1973) showed Coleman Kamloop RB to exhibit a lower initial harvest, a higher annual survival rate, and a higher weight return than plants of Mt. Shasta RB and Mt. Whitney RB strains. Rawstron (1977) found weight returns for Mt. Shasta RB, Mt. Whitney RB, and Coleman Kamloop RB, respectively, to be 139.5%, 180.8%, and 218.7% in one fishery, and 90.1%, 108.9%, and 129.2% in a second fishery. In both fisheries, Coleman Kamloop RB gave the greatest yield followed by the Mt. Whitney RB and then the Mt. Shasta RB strain. Initial harvests (before October 1) were highest for Mt. Shasta RB, intermediate for Mt. Whitney RB, and lowest for Coleman Kamloop RB. Rawstron (1972) documented a significant difference in first-year exploitation rates. for Mt. Whitney RB (14%) and Kamloop RB (9%) but not in second-year rates of 14% and 17%, respectively. The Sand Creek RB strain had the best average return rates of five strains in five separate stream fisheries, although overall returns were not significantly different among strains (Fay and Pardue 1986).

Though many authors document differences in returns among strains, duplication of experiments has often failed to produce similar results. Returns within strains may vary among waters or among years in the same water. Hudy (1980) reported the Tensleep RB strain had the highest return (33.7%), followed by Shepherd-of-the-Hills RB (11.0%), Beity RB (5.5%), Sand Creek RB (5.4%), New Zealand RB (4.1%), and Fish Lake RB x DeSmet RB (2.9%) in Porcupine Reservoir, Utah. The next year, however, returns were similar among the Tensleep RB, Sand Creek RB, and Shepherd-of-the-Hills RB strains (6.5-7.6%; Hudy and Berry 1983).

Differences in performance or returns among strains may be related to differences in size or condition at stocking. In East Canyon Reservoir, Utah, Babey (1983) found returns from the Tensleep RB strain (74%) were better than those from Sand Creek RB (12%) or Shepherd-of-the-Hills RB (14%) strains. The following year, with hatchery rearing standardized, returns were 45%, 35%, and 20% respectively (Berry et al. 1982).

Wild rainbow trout strains planted at catchable sizes typically have lower returns than domesticated strains. In a Montana study conducted over 2 years, 60-83% of the stocked domestic strains (Spring Standard Growth and Winthrop) were harvested while no more than 30% of the wild strains (McConaughy RB and Fish Lake RB) were harvested (Dwyer and Piper 1984). Kmiecik (1980) reported lower returns for wild strains (DeSmet RB x McConaughy RB) than for two domestic strains, and concluded the difference was due to lower catchability of the wild fish.

Though wild strains may have lower returns, they may provide other benefits. The greater longevity of and avoidance behavior of wild strains have proven useful in that they remain in the fishery longer. This makes them accessible to anglers for a longer time and allows a greater return by weight (Rawstron 1973; Close and Hassinger 1981; Ayles and Baker 1983).

Survival

Among rainbow trout strains, both hatchery and post-stocking survival rates may vary (Rawstron 1972; Rawstron 1973; Rawstron 1977; Hudy 1983; Reininger 1984; Partridge 1985; Hensler 1987). Authors have separated. survival into two categories: 1) survival-to-the-creel (i.e. returns), and 2) true survival. Survival to the creel information is summarized in the catch rates and return section.

Actual survival of an introduced rainbow trout population is considered when trying to maximize potential harvest. Rawstron (1972) calculated second-year survival to be 97% for Coleman Kamloop RB and 21% for Mt. Whitney RB. He noted the estimate for Kamloop RB was probably high due to small sample size, but believed greater survival of Kamloop RB was due to more rapid movement to the limnetic zone. In two separate fisheries, Rawstron (1973) estimated annual survival for Coleman Kamloop RB (15.6%) to be greater than Mt. Shasta RB (7.6%) in 1969. In 1970 results for the same fishery indicate survival rates for Coleman Kamloop RB, Mt. Shasta RB, and Mt. Whitney RB to be 25.4%, 5.1%, and 12.2% respectively. As in the previous year, Kamloop RB had the lowest natural mortality rate. In another fishery, Coleman Kamloop RB again had the highest survival rate of 6.1%. Rawstron (1977) found second-year survival (holdover) rates of 3% for Mt. Shasta RB, 11% for Mt. Whitney RB, and 17% for Coleman Kamloop RB. The Kamloop RB strain has demonstrated great longevity with fish persisting up to 5 years (Close and Hassinger 1981). Based on spring gillnetting, Dwyer and Piper (1984) concluded McConaughy RB strain fish were more abundant than Fish Lake RB strains, indicating a much better ability to survive in a pond environment. Both strains remained in the fishery for up to 4 years. In Canadian aquaculture lakes, Idaho strain rainbow trout had a higher survival than the Pennask RB strain (27.9% versus 16.3%), but when compared to Tunkwa RB strains the following year, it had similar survival (13.3% versus 16.5%; Ayles 1975). Ayles and Baker (1983) showed survival of Idaho fish (strain not given) was better than the Pennask RB, poorer than the Mt. Lassen RB, Sunndalsora RB, and Nisqually RB fish, and not significantly different from the Tunkwa RB or Manx RB strains.

Several authors reported better survival and longevity for wild strain fish than for domestic fish. Brauhn and Kincaid (1982) suggest when Fish Lake RB and Wytheville RB strains were stocked at high densities, survival of Fish Lake RB strains was greater. Kmeicik (1980) believed survival of fingerling hybrid strain rainbow trout (less domesticated) was greater than the domestic Nevin RB strain because it was less catchable. Hensler (1987) reported maximum longevity for the wild DeSmet RB strain to be 5 years followed by Eagle Lake RB (3 years) and the domestic Arlee RB strain (2 years).

Lake characteristics can have important effects on trout survival regardless of strain. In one of the most comprehensive strain evaluations we reviewed, Ayles and Baker (1983) assessed relative survival of eight strains of rainbow trout and their hybrids in multiple test waters over 6 years. They found that differences among lakes accounted for 66-97% of the total variability in mean survival. Strain accounted for only 1-39%, and lake x strain interaction accounted for 2-28% of the variability in survival. Differences in productivity and habitat appear more important than strain differences in determining survival; the difference in survival among strains is of little importance if sufficient habitat does not exist (Borowa 1990).

Reproduction

The potential for reproduction is not a consideration in most hatchery trout stocking programs unless trying to rebuild or establish natural stocks. Stream or reservoir characteristics that preclude endemic trout from successfully spawning typically also limit hatchery trout. However, where habitat is adequate, naturalized self-sustaining trout populations have become established through stocking. The McConaughy RB strain in Nebraska probably originated from early plants in the North Platte Valley from 1911 to 1945 (Van Velson 1978). A run of large adfluvial fish developed after McConaughy Reservoir was built. Colorado has also had success establishing naturalized rainbow trout populations in the upper Rio Grande and Gunnison rivers using a wild fluvial stock (Nehring 1992).

Establishment of naturalized populations depends on using a stock or strain endemic to the region, or one that is adaptable enough to survive and reproduce. Domesticated hatchery strains generally are easily harvested, do not survive more than 2 years under natural conditions and are unlikely to contribute to natural recruitment (Dwyer and Piper 1984). Klein (1983) found that the wild DeSmet RB strain contributed more to inlet spawning than did domestic fish in Lake Parvin, Colorado. Wild fish have more genotypic variation, are more wary, longer-lived, and more able to respond to environmental changes. The use of domesticated stocks to re-establish natural populations is probably unrealistic.

The availability of wild fluvial rainbow trout strains for introductions is limited. The Colorado River rainbow trout has potential to establish naturalized stream populations, and readily disperses to occupy vacant habitats. If they are expected to survive and reproduce, however, they must be protected from harvest until they can mature and spawn (Nehring 1992).

Domestic strains are often selected for early maturity (at 2 years) in the hatchery. The physiological stresses of maturation often lead to significant mortality in the wild when spawning habitat is not available. Consequently, development of older, larger age classes of domestic strains does not occur (Rawstron 1973). Using wild strains with late maturity can increase the trophy potential of hatchery trout waters, even without natural reproduction. Unfortunately, few wild stocks with this characteristic exist, and selection of hatchery strains to increase age at maturity would also increase broodstock maintenance costs.

Cost

Describing cost to the creel is an important way to assess the effectiveness of stocking strategies. Costs to rear and stock fish can vary greatly from hatchery to hatchery, depending on the level of automization, water temperatures, feed costs, etc. In Idaho, costs to rear and plant catchable-size trout (various strains) range from $0.19 to $1.93 per fish and average about $0.54 per fish (Job 3, this report). Rearing costs can also vary among strains of trout (Borgeson 1964; Cordone and Nicola 1970; Rawstron 1972; Rawstron 1973; Rawstron 1977; Partridge 1984), but this variability is probably small compared to cost variability across hatcheries.

Domesticated strains are more suited to hatchery conditions, and typically grow faster and more uniformly than wild strains (Cordone and Nicola 1970; Hansen and Stauffer 1971; Dwyer and Piper 1984; Partridge 1988). Hatchery food conversion efficiency is generally poorer in wild strains (Dwyer and Piper 1984; Partridge 1988).

Cost-to-the-creel depends on hatchery costs and the proportion (by numbers or weight) of stocked fish harvested. Because wild strains may be less catchable (Kmiecik 1980; Dwyer and Piper 1984), returns may be relatively poor and cost to the creel high compared to catchable-size domestic fish. Rawstron (1972, 1973, 1977) compared cost-to-the-creel for three domestic strains of catchable rainbow trout in several California reservoirs. Coleman Kamloop RB were consistently more cost-effective than the Mt. Whitney RB or Mt. Shasta RB strains. Jackson and Lovgren (1992) concluded that using catchable-size Spokane RB rather than another strain with poorer returns could allow Washington hatcheries to decrease total rainbow trout production and save over $350,000 annually. Their conclusions were, however, based on strain comparisons in only four waters over 2 years.

In put-and-grow programs, the higher hatchery costs of wild strains may be offset by better post-stocking survival and growth (Cordone and Nicola 1970; Hansen and Stauffer 1971; Rawstron 1972). Cordone and Nicola (1970) compared cost-to-the-creel of fingerling wild Kamloop RB and the domestic Virginia RB, Mt. Whitney RB, and Mt. Shasta RB strains. Kamloop RB had lower cost-to-the-creel than the Virginia RB and Mt. Whitney RB strains but a higher cost than the Mt. Shasta RB strain. Although return rates (and costs) may vary among strains, it is clear that many other factors influence returns of put-and-grow trout (Ayles and Baker 1983). The most cost-effective strain under one set of conditions may not be so under different conditions.

CONCLUSIONS

Most strain evaluation studies are site- and time-specific. Most studies we reviewed included few or no spacial or temporal replications. In those that did, strain performance results were often inconsistent or contradictory. Appendix A provides a list of available behavior and performance data for 17 rainbow trout strains summarized from the papers we reviewed. For most strains, this information is either insufficient or conflicting, and is probably inadequate for making strain selection decisions for individual fisheries.

Lake-to-lake and year-to-year environmental effects often clouded the strain effects on performance. Variability in broodstock quality, rearing environment, size of fish stocked, time and date of stocking, and the fishery environment may create biases and misinterpretation of field performance traits (Ayles and Baker 1983; Kincaid and Berry 1986). Despite many years of strain evaluation studies, few specific guidelines for strain selection have been developed.

On a broad scale the importance of strain selection for put-and-take fisheries appears small and inconsistent. Strain selection can, however, improve stocking efficiency for individual fisheries, provided strain comparisons in the fishery are comprehensive (e.g. Maiolie 1987; Schneidervin and Brayton 1992). Most domesticated strains could probably perform well in put-and-take fisheries provided they are of acceptable size to the angler and are in good health and condition at stocking. Wild strains are typically less catchable than domestic strains, and would have little application in most put-and-take programs. In put-and-take fisheries where long-term growth and survival is desired, strain selection may be more important, but we *cannot* reliably recommend any one strain with the available information.

Because strain is probably unimportant in most put-and-take rainbow trout programs, we should focus on finding the most reliable source of eggs regardless of strain. Our reliance on commercial egg sources will continue to make it difficult to consistently provide specialty strains (especially wild strains).

In put-and-grow fisheries, stocked fish are usually expected to survive and grow for 6 months to 1 year before entering the fishery. Strain selection is more important in this case. Domestic strains do not survive well under natural conditions, and may not provide cost-effective returns. Wild strains generally have superior survival and growth, and may be longer-lived than domestic strains. In waters with the potential to produce trophy trout, selection of a late-maturing strain may be especially important.

We currently maintain two of our own domestic broodstocks (Hayspur RB and Kamloop RB) and have started another wild fluvial broodstock (Colorado River RB). It may be important to consider starting another wild broodstock for lake and reservoir fingerling programs. While initial costs would be high, over the long run it would decrease our dependency on out of state eggs and stabilize production. This would also free up our domestic broodstocks for catchable production. Another approach would be to periodically infuse wild genes into our current Kamloop RB broodstock.

Though the benefits of strain manipulation appear uncertain and unpredictable, our biologists continue to experiment with new strains. Selection of experimental strains is often based on limited information. Given the uncertainties, any proposals for experimental strains should be accompanied by an evaluation plan to document costs and benefits. New strains should be stocked with same-size fish from our current broodstocks for performance comparisons.

Our domestic broodstock have historically been selected for early maturity (at 2 years) in the hatchery. After release, these fish rarely persist in the fishery beyond 2 or 3 years of age, presumably because of high natural mortality associated with maturation and spawning (Purdom and Lincoln 1973). This alone could significantly limit the trophy potential in fisheries supported by domestic hatchery fish. Selecting for delayed maturity in our domestic broodstocks could improve longevity of stocked fish and increase the potential size. Even 1 additional year of growth could substantially enhance the trophy component of hatchery trout fisheries.

RECOMMENDATIONS

1. Reduce the number of rainbow trout strains we use for put-and-take programs. Find strains with reliable sources and make long-term commitments to purchase them (long term production planning).

2. Increase emphasis on our own broodstock production for both put-and-grow and put-and-take. Consider establishing another wild lacustrine broodstock for put-and-grow in lakes and reservoirs, or infuse wild genes into our current Kamloop RB broodstock.

3. Requests for experimental strains should be accompanied by an evaluation plan to assess benefits. All experimental strains should be stocked with same-size fish from our own broodstocks for comparisons.

4. Select for maturity at 3 years in our domestic broodstocks to increase longevity and growth potential after release.

LITERATURE CITED

Ayles, G.B. 1975. Influence of the genotype and the environment on growth and survival of rainbow trout (Salmo gairdneri) in central Canadian aquaculture lakes. Aquaculture 6:181-188.

Ayles, B.G. and R.F. Baker. 1983. Genetic differences in growth and survival between strains and hybrids of rainbow trout (Salmo gairdneri) stocked in aquaculture lakes in the Canadian prairies. Aquaculture 33:269-280.

Babey, J. B. 1983. Evaluation of three strains of rainbow trout stocked in a reservoir where the ectoparasite Lernia cvprinacea is endemic. Master's Thesis, Utah State University, Logan, Utah.

Boles, H.D., F.A. Meyer, and D.P. Borgeson. 1964. Packer Lake experimental trout management. California Department of Fish and Game, Inland Fisheries Administrative Report No. 64-12.

Borawa, J.C. 1988. Comparison of 1/2 wild and domestic brown trout fingerling introductions into southern Appalachian streams. Final Report, North Carolina Wildlife Resource Commission.

Brauhn, J.L. and H. Kincaid. 1982. Survival, growth, and catchability of rainbow trout for four strains. North American Journal of Fisheries Management 2:1-10.

Close, T. and R. Hassinger. 1981. Evaluation of Madison, Donaldson and kamloops strains of rainbow trout, Salmo gairdneri, in Lake Superior. Minnesota State Division of Fish and Wildlife, Project F-26-R, Study 209.

Cordone, A.J., and S.J. Nicola. 1970. Harvest of four strains of rainbow trout from Beardsley Reservoir, California. California Fish and Game 56:271-287.

Dolan, J.J., and R.P. Piper. 1979. Hatchery and field evaluation of four strains of rainbow trout. U.S. Fish and Wildlife Service, Developments in Fish Culture, Bozeman Information Leaflet No. 10.

Dwyer, W.P., R.G. Piper, and J.K. Morrison. 1980. The second year of hatchery and field evaluations of four strains of rainbow trout. U.S. Fish and Wildlife Service, Developments in Fish Culture, Bozeman Information Leaflet No. 12.

Dwyer, W.P. and R.G. Piper. 1984. Three year hatchery and field evaluation of four strains of rainbow trout. North American Journal of Fisheries Management 4:216-221.

Fay, C.W. and G.B. Pardue. 1986. Harvest, survival, growth, and movement of five strains of hatchery-reared rainbow trout in Virginia streams. North American Journal of Fisheries Management 6:569-579.

Flick, A.W. and D.A. Webster. 1964. Comparative first year survival and production in wild and domestic strains of brook trout, Salvelinus fontinalis. Transaction of the American Fisheries Society 93:58-69.

Flick, W. and D. Webster. 1976. Production of wild, domestic, and interstrain hybrids of brook trout (Salvelinus fontinalis)in natural ponds. Journal of the Fisheries Research Board of Canada 33:1525-1539.

Fraser, J. 1981. Comparative survival and growth of planted wild, hybrid, and domestic strains of brook trout (Salvelinus fontinalis) in Ontario lakes. Canadian Journal of Fisheries and Aquatic Sciences 38:1672-1684.

Hansen, M.J., and T.M. Stauffer. 1971. Comparative recovery to the creel, movement and growth of rainbow trout stocked in the Great Lakes. Transactions of the American Fisheries Society 100:336-349.

Heimer, J.T. 1984. American Falls - Snake River fisheries investigations. Final report to Idaho Power Company for Idaho Department of Fish and Game.

Hensler, M.E. 1987. A field evaluation of four strains of Salmo introduced into seven Montana waters. Masters Thesis, Montana State University, Bozeman, Montana.

Hudy, M. 1980. Evaluation of six strains of rainbow trout stocked as fingerlings in Porcupine Reservoir, Utah. Master's Thesis, Utah State University, Logan.

Hudy, M. and C.R. Berry, Jr. 1983. Performance of three strains of rainbow trout in a Utah reservoir. North American Journal of Fisheries Management 3:136-141.

Jackson, S. and T. Lovgren. 1992. Field performance evaluation of three rainbow trout broodstocks in western Washington lowlands lakes. Progress Report No. 92-19, Washington Department of Wildlife, Olympia, Washington.

Kincaid, H.L. 1981. Trout strain registry. U.S. Fish and Wildlife Service, National Fisheries Center, Report NFC-L/81-1, Leetown, West Virginia.

Kincaid, H.L. and C.R. Berry, Jr. 1986. Trout broodstocks used in management of national fisheries. Pages 211-222 in R.H. Stroud, editor. Fish culture in fisheries management. American Fisheries Society, Bethesda, MD.

Klein W.D. 1983. Lake DeSmet rainbow trout in Parvin lake, CO 1972-1978. Colorado Division of Wildlife. Special Report No. 55.

Kmiecik, N.E. 1980. An evaluation of rainbow trout strains in the sport fishery of three Wisconsin lakes and for trout ranching in Minnesota winterkill lakes. Master's Thesis, University of Wisconsin, Madison, WI.

Maiolie, M.A. 1987. Ashton Reservoir fishery enhancement evaluation. Job Completion Report, Idaho Department of Fish and Game, Boise, ID.

Moring, J. 1982. An efficient hatchery strain of rainbow trout for stocking Oregon streams. North American Journal of Fisheries Management 2:209-215.

Needham, P.R. and R. J. Behnke. 1962. The origin of hatchery rainbow trout. Progressive Fish-Culturist 24:156-158.

Partridge, F.E. 1985. Lake and reservoir investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-7, Job 2, Boise.

Partridge, F.E. 1988. Lake and reservoir investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-9, Job 2, Boise.

Purdom, C.E. and R.F. Lincoln. 1973. Chromosomal manipulation in fish. Pages 83-90 in J.H. Schroder, editor. Genetics and mutagenesis of fish. Springer-Verlag, Berlin and New York.

Rawstron, R.R. 1972. Harvest, survival, and cost of two domestic strains of tagged rainbow trout stocked in Lake Berryessa, California. California Fish and Game 58:44-49.

Rawstron, R.R. 1973. Harvest, mortality, and cost of three domestic strains of tagged rainbow trout stocked in large California impoundments. California Fish and Game 59:245-265.

Rawstron, R.R. 1977. Harvest, survival and weight returns of tagged Eagle Lake and Coleman rainbow trout stocked in Lake Berryessa in 1972. California Fish and Game 63:274-277.

Reininger, B. 1984. Alternative trout strains for fishery enhancement. Job Performance Report, Project F-73-R-6, Idaho Department of Fish and Game, Boise, ID.

Schneidervin, R.W. and S.L. Brayton. 1992. Evaluation of three strains of rainbow trout in Flaming Gorge Reservoir Utah-Wyoming. Publication No. 92-5, Utah Department of Natural Resources, Salt Lake City, Utah.

Wood, E.M. 1953. A century of American fish culture, 1853-1953. The Progressive Fish Culturist 1953:147-162.

Appendix A. Summary of available behavior and performance characteristics of rainbow trout strains commonly used in Idaho fisheries. "I" denotes insufficient information to draw conclusions; "C" indicates conflicting studies.

Strain	Behavior			Survival after stocking	Best susceptibility to angling	Growth	Recommended use [a]
	Emigration	feeding	habitat preference				
Hayspur	low	piscivorous at 200-250 mm	littoral	I	CS	I	PT, PGT
Domestic Kamloops (Idaho stock)	I	I	1	low	I	I	I
Gerrard Kamloops	I	piscivorous at 450 ma	pelagic	CS	boat anglers	to 12 kg with kokanee	PGT, PGTS
Spokane	I	I	1	I	I	I	I
Colorado River (wild fluvial stock)	high in streams	I	I	above average in streams	I	above average	PGT streams
Pennask	1	I	I	I	I	I	1
Mt. Lassen	high	I	littoral	I	shore anglers	I	I
Eagle Lake	I	CS	CS	I	1	I	PGT, PGTS
Erwin	I	I	I	I	I	I	PT
Arlee	1	I	I	I	I	I	PT, PGT
Mt. Shasta	I	piscivorous at 300-325 mm	I	I	CS	I	PT
McCanaughy	I	piscivorous at 300-325 am	I	I	I	I	PG, PGT reservoirs
DeSmet	I	CS	I	I	low		PGT, establish populations in reservoirs
Mt. Whitney	high	1	1	I	CS	I	I
Tasmarian	I	I	I	I	I	I	I
Kamloops[b] (various stocks)	I	generally piscivorous	pelagic	CS	generally boat anglers	I	PT, PGT, PGTS
Ennis	1	I	I	I	I	I	PT

[a] PT = put-and-take; PGT = put-grow-and-take; PGTS = put, grow, and take and spawning

[b] Includes Coleman, Junction, Trout Lodge, and Skanes Kamloops

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